2022 Research Results

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

USDA United States Department of Agriculture
Agricultural Research Service

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AREA 4 SCD
Cooperative Research Farm

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STATEMENT FROM THE RESEARCH LEADER

Dr. David Archer

At a research lab like the Northern Great Plains Research Laboratory, it is important to do quality research. But, just doing quality research is not enough, it needs to be useful, and the results need to get to those who can use them.

In 2022, we spent the year not only doing good research, but in also developing our research plans for the next five years. This planning period is always an exciting time when we make sure that we take extra time to listen and understand your research needs and when we think about ways to improve how we communicate our research to you. At the NGPRL effective communication is more than showing you our results' we feel that effective research is including you, our stakeholders, in all aspects of the research process.

This Research Results report is one way we hope to do that. In this report we provide updates on our research including insights into our research activities, descriptions and interim results from ongoing studies, and ground-breaking research findings. You will find some changes from previous Research Results as we welcome new ideas from Seth Archer, our new Technical Information Specialist and editor of this report. We invite you to provide feedback on the report and other suggestions you may have for better communicating our research.

I am happy to present the 2022 Research Results report.

Statement from the Editor

As the new Technology Information Specialist at the Northern Great Plains Research Laboratory in Mandan, I am writing this note to explain updates made to the annual Results Report. My hope is to make this annual publication a space to share more information about the wide range of scientific discovery happening in the NGPRL.

There are four major sections to this report.

1. General information
2. Featured Research
3. NGPRL Research Bibliography 2022
4. Long Term Studies Update

This first section, **GENERAL** section, is a section meant to be light reading surrounding things happening at the laboratory. This year we have an article from about their international collaboration with a major laboratory in Germany and an informative breakdown on a major publication project from the LTAR Human Dimensions Working Group, led by the NGPRL.

The **FEATURED RESEARCH** section includes a few articles from ongoing research, chosen by the research staff. Some of these features cover published articles, some of the information will soon be published. This section includes a cross section of research happening *now* at NGPRL, as self-selected by the researchers.

The **NGPRL BIBLIOGRAPHY** is intended to be a comprehensive approach to almost all the work shared in the public sphere in the year 2022. In addition to the basic citations, brief, scannable, many short summaries have been included to offer a quick and accessible approach to the range of work at NGPRL.

Last, Is the **LONG-TERM STUDY UPDATE** section. This section is largely data driven. There are updates on the Soil Quality Management study, the Croplands Common Experience study, the Integrated Crop & Livestock study, the Bioenergy Cropping Systems study, the Area IV Farm, and the Variety Trials data courtesy of Hettinger Extension Research Center.

I hope this annual Results creates value in the way stakeholders approach the NGPRL Research Results Report. If you have questions, concerns, or comments, please feel free to reach out to me directly at Seth.Archer@USDA.gov

Thank you for reading.

Seth Archer
Technical Information Specialist
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GENERAL INFORMATION FROM NGPRL

Please follow the link below to access the special issue in its entirety.
https://www.sciencedirect.com/journal/rangelands/vol/44/issue/5

Special Issue – *Rangelands* vol 44 iss 5
Soil science and human well-being advancements

by David Toledo

The USDA Long-term Agroecosystem Research (LTAR) Human Dimensions Working Group, which is led by the NGPRL, published a special issue in the journal *Rangelands* on the **Emergence of Social Science with the USDA-ARS and LTAR network**.

This special issue, a collection of papers surrounding the same topic, provides examples of approaches that include scientist-stakeholder-practitioner collaborations and synthesizes natural and social sciences information to address complex natural resource issues.

A few of the findings within this special issue that highlight the importance of the inclusion of social science in rangeland science and management include but are not limited to the importance of establishing and maintaining relationships to enhance collaborative efforts during management challenges such as large wildfires; the beneficial outcomes that can result from time and energy commitment in intentional, localized relationships; identifying landowner willingness to apply preventative action when faced with invasive species; and advances in the theoretical background on human well-being.

Rangelands began publication in 1974 and is the key research publication for the Society of Rangeland Management.

It functions as a forum for facts, ideas, and philosophies about the study, management, and use of rangelands.

Special Issue: Introduction

"**Infusing 'long-term' into social science rangelands research**" explains how social science rangelands research has advanced substantively in the last few decades as a multidisciplinary endeavor, and notably through increased capacity to integrate with ecologically centered approaches.

The diversity of social science-related contributions to rangelands research continues to expand with both breadth and depth of approaches, perspectives, and backgrounds of participating scholars. The USDA Long-term Agroecosystem Research (LTAR) Network advances a unique long-term and large-scale effort to incorporate social science research into a long-term "common experiment" across multiple sites within varied rangelands contexts of the United States.

Management

"**Effects of wildfire on collaborative management of rangelands: A case study of the 2015 soda fire**" provides a valuable case study that uses interview data to examine cross-boundary collaboration after the Soda Fire that burned approximately 113,312 ha (280,000 acres) of southwestern Idaho and southeastern Oregon.

This paper documents how rangeland management challenges such as "mega" wildfires benefit from existing relationships. They found that relationships established in other management contexts were activated by individuals within agencies to share funding and resources to rehabilitate the landscape after the Soda Fire. However, barriers to collaborative efforts still exist; however, interviewees highlighted the importance of individual agency (bottom-up) changes in lessening top-down constraints.

"Social learning lessons from collaborative adaptive rangeland management" provides an in-depth review of the Collaborative Adaptive Rangeland Management (CARM) effort where researchers used social science to evaluate group learning. The paper documents beneficial outcomes that can result from time and energy commitment in an intensive set of intentional localized relationships.

The Collaborative Adaptive Rangeland Management project is a case of a ranch-scale, 10-year grazing experiment ongoing in Colorado. The paper describes the complex, challenging aspects of the collaborative process, and how those challenges helped inspire learning as the team grappled with new problems and knowledge. Social science showed how respect, trust, and shared understanding are essential to success and engaging stakeholders.

Livelihoods

"Measuring the social and ecological performance of agricultural innovations on rangelands: Progress and plans for an indicator framework in the LTAR network" explains the development of the LTAR Agricultural Performance Indicator Framework which evaluates how agricultural innovations perform relative to sustainable intensification goals in five domains: Environment, Productivity, Economic, Human Condition, and Social. This paper documents a long-term effort occurring within LTAR to design a suite of sustainable intensification indicators that ground the national mission of the network in metrics to enable the science. They present a method for measuring outcomes of management innovations against site-specific benchmarks, which can be applied in grazinglands worldwide.

"Private landowners and the facilitation of an invasive species" explores private landowner perceptions about the invasive grass, Kentucky bluegrass, in the US northern Great Plains. Their surveys-based scenario approach indicated little to no preventative action by landowners and demonstrated the lag between social perception, ecological effects, and the cascading effects that can result. Cascading impacts will become more evident as invasion and time progress and incentivizing early action to prevent further invasion is key to maintaining these working landscapes.

Well-being

"Sense of place on the range: Landowner place meanings, place attachment, and well-being in the Southern Great Plains" reports on a quantitative analysis of sense of place on rangelands in the Edwards Plateau, Central Great Plains, and Flint Hills and found landowners have diverse senses of place based on a variety of place meanings and differing levels of place attachment.

Despite social and ecological regional differences, sense of place was similarly diverse within each region rather than specific to region. They found that personal experiences related to way of life, peace and quiet, personal legacy, autonomy, and inspiration may be fundamental meanings for place attachment and well-being on private lands. As such, it is important to include sense of place in efforts toward socially and environmentally sustainable private lands management.

"Communal processes of health and well-being for rangelands research and practice" presents the challenge for the integration of social-ecological research in the development and assessment of sustainable agricultural production: commonly used concepts like ecosystem services do not represent all environmental processes that support or degrade health and well-being. This paper focuses on the often-underrepresented example of communal processes.

Communal processes include social interactions for a common interest or purpose, or for deliberation and decision-making about a shared locality. Many (but not all) communal processes foster relationships that strengthen a community's capacity for collective action while helping individuals and families cope with environmental stressors. This paper advances theoretical background on communal processes in well-being in the context of complex rangeland landscapes.

General concluding trends

"Integrating human dimensions within the LTAR Network to achieve agroecological system transformation" recommends a unique framework based on the work of a cohort of human dimensions postdocs that emerged within LTAR. They propose a four-step framework for the LTAR Network to evolve a cohesive human dimensions strategy that brings together the social and ecological sciences.

Their framework provides a basis for the large network science effort to "evolve a cohesive human dimensions strategy" that integrates social and ecological elements of research. They conclude that continued institutional support is required to maintain and further pursue research that will support stakeholder co-developed science that facilitates agroecosystem transformations benefiting society.

"The future of social science integration in rangelands research" provides a concluding overview that forecasts future pathways of social science integration into rangelands research and a call to action about continuing to diversify inquiries. To address questions of rural prosperity and collaborative management, social scientists and the Long-Term Agroecosystem Research (LTAR) Network must turn their attention to the perspectives, practices, and experiences of indigenous, non-Anglo, female, and "new rural" rangeland stakeholders as well.

Social science researchers can learn from scholars in related fields whose work is less often consulted in rangeland science, including those working internationally with pastoral communities and in the United States with rural youth. Understanding these communities is likely to require broadening our conceptions of what constitutes "knowledge," with a greater focus on seeking just outcomes for the full range of people who depend upon rangelands and rangeland communities for their lives and livelihoods.

Quantifying resilience: International collaborative science

This approach is new for the NGPRL Research Results. This is a short narrative on one researcher's recent experience travelling to follow developing research threads. The inclusion of this in a Research Results report is meant to demonstrate the collaborative and complex nature of research.

by Andrea Clemensen

Ecometabolomics is an evaluation of how a plant is communicating with its environment. Dr. Nicole van Dam's research first expanded my interest from specific plant secondary metabolites to the world of ecometabolomics. As a researcher, it was a larger realm of possibilities to understand dynamics between plants and their environment. After establishing a collaboration with Nicole's team at the Ecometabolomics Platform for Ecology and Biodiversity Research (EcoMetEoR) and planning to visit their lab in January 2023, it was deflating to learn the platform might collapse with Nicole's retirement at the end of 2022.

The George Gate located within the Innere Altstadt. Dresden, Germany. Photo by Andrea Clemenson

Seeking other options to continue this new and important research thread, I found potential opportunities with Drs. Mike Bukowski, James Harnly, and Jianhao Sun at the USDA-ARS Methods and Application of Food Composition Laboratory in Beltsville, MD. They agreed to join my quest to establish in-house analytical capabilities for ecometabolomics within the ARS, and Jianhao agreed to join me in Leipzig for the last week of training to continue this research on ecometabolomics.

A pedestrian district just off of Bruhl's Terrace on the Elbe River in Dresden

Fast forward to 2023, where, after 28 hours of traveling with 480 freeze-dried and ground samples, I arrived in Leipzig, Germany to start a new laboratory learning adventure. There I began my work with The German Centre for Integrative Biodiversity's (iDiv) EcoMetEoR to process the 480 samples. The goal is to determine whether different management of corn (LTAR experiment) and genetic variety and/or management of wheat (Integrated Crop

Livestock experiment) influences plant metabolites differently.

iDiv is in the center of 3 German universities – Martin Luther University Halle-Wittenberg, Friedrich Schiller University Jena, and Leipzig University – and it operates in cooperation with the Helmholtz Centre for Environmental Research. My time at iDiv included two weeks of sample preparation; two weeks of learning new software for metabolomic assessment, annotation, and data analysis; and an invited presentation where I shared the history of the ARS and the research conducted at the NGPRL.

My hosts in Leipzig took a deep interest in the presentation of the work at the ARS. They appreciate the pursuit of applicable research within real-life settings. I shared our current objectives for the Healthy Soil, Healthy Food, Healthy People Initiative, and my view that ecometabolomics was a metric to assess environmental impact in food production, and a way to quantify ecosystem resilience. This collaborative research project between ARS and iDiv, in understanding ecosystem resilience, includes the evaluation of how interacting ecosystems adapt to change and may provide management guidelines for producers to expand the resilience of their farms.

Ecometabolomics is a valuable tool to quantify agroecosystem resilience in food crops and forages and I look forward to sharing with you the research that will come from my time at the iDiv.

The German Centre for Integrative Biodiversity Research (iDiv)

Featured Research

Saponin Concentrations in Two Switchgrass Cultivars

Dr. Andrea Clemensen

Clemensen, A. K., Lee, S. T., Mitchell, R. B., Schmer, M. R., & Masterson, S. D. (2023). Steroidal saponin concentrations in switchgrass cultivars Liberty and Independence in North America. *Crop, Forage & Turfgrass Management*, 9, e20204. https://doi.org/10.1002/cft2.20204

This study on switchgrass provides initial information that may be useful to producers in selecting switchgrass varieties. Continued research will explore how switchgrass may impact agricultural ecosystems. This preliminary study has determined concentrations of saponins in switchgrass cultivars Liberty and Independence. Continued research may pursue the impact of switchgrass saponins on soil and water dynamics, forage use, and pest resistance.

Switchgrass (Panicum virgatum L.) is a warm-season grass native to the tallgrass prairie in North America and offers several benefits to agricultural systems including an increase in soil organic carbon. Switchgrass can be used for biofuel or as forage for cattle, but it should not be grazed by horses since there are compounds that are toxic to horses. These compounds, steroidal saponins, are plant secondary metabolites that have antibacterial and antifungal characteristics and are likely the reason switchgrass can withstand various environmental hardships such as insect infestation and disease. Saponins may influence soil nutrient cycling by decreasing N loss and may also influence soil water dynamics by increasing soil water holding capacity.

Switchgrass varieties “Liberty” and “Independence” are two important bioenergy cultivars for the Great Plains. However, the steroidal saponins in these two switchgrass cultivars have not been investigated. In order to pursue research on the potential effects steroidal saponins from these two cultivars may have on soil nutrient and water dynamics, seasonal forage use, and/or pest resistance, determining the relative concentration of steroidal saponins was needed.

Liberty switchgrass at work. Photo by Robert Mitchell.

This study determined the relative steroidal saponin concentration in leaf and stem tissues of both cultivars. Both cultivars had three types of steroidal saponins: protodioscin, dichotomin, and saponin B. The three types of steroidal saponins were greater in the leaf than stem tissues in both cultivars. There were also significant differences in the steroidal saponin concentrations between the two cultivars. Protodioscin and saponin B were greater in Independence than Liberty, and dichotomin was greater in Liberty than Independence. Additional research should shed light on how producers can best use these differences to benefit their agricultural ecosystem.

North Dakota landowners evaluate invasive grasses based on impact to ecosystem services

Dr. David Toledo

In this study we emphasize the difficulty of motivating landowners to act proactively against invasive species, especially in the early stages of an invasion when the impacts may not yet be clear. We go on to propose that incentive programs, collaborative landscape planning, and external regulations could offer solutions. We also emphasize the importance of reconciling scientific information with local knowledge and experiences and the need for designing interventions that consider landowner needs and prioritize ecosystem service tradeoffs.

As part of a research collaboration that began in 2016 through a Non-Assistance Cooperative Agreement with Mike Sorice at Virginia Tech, we explored how North Dakota Landowners evaluate invasive grasses on their land through the lens of ecosystem services. We used a survey that asked landowners about their experiences and perspectives on Kentucky bluegrass, including their familiarity with the species, their management goals related to it, and their perceptions of its acceptability.

Data from our survey found that many landowners were unfamiliar with Kentucky bluegrass and had no goals for managing it. Among those who did have the species on their land, only a minority expressed a goal of decreasing it, while others intended to maintain or had no goal for it. Overall, landowners were ambivalent about Kentucky bluegrass, with most rating it as neither acceptable nor unacceptable.

We then used a scenario-based approach within the survey to understand these landowner responses. We presented landowners with short narratives describing the impacts an unnamed invasive grass species expanding on native rangeland would have on forage availability, quality, and yield, floral resources for pollinators, and water infiltration and availability. We then

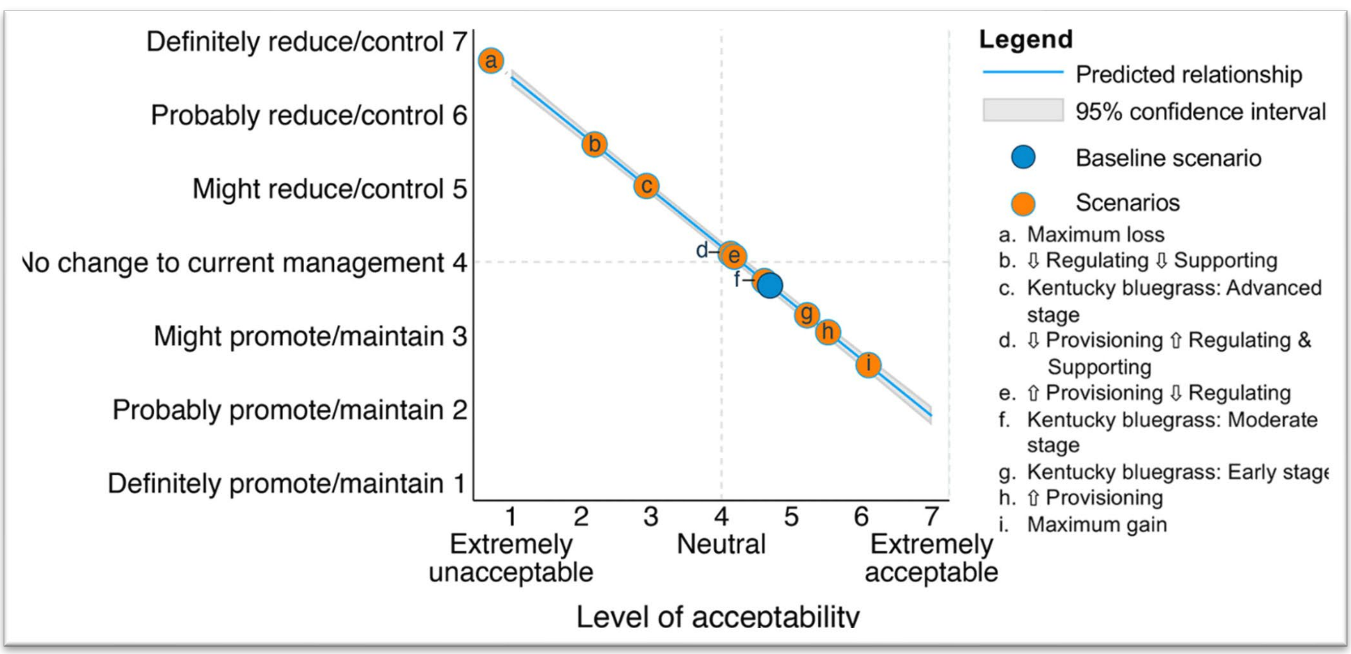


Figure: The relationship between landowners' expected acceptability ratings of a new grass and their expected management intentions (as published in Rajala et al. 2021).

asked landowners to indicate the acceptability of the grass on their rangelands and their management intentions for the grass based on these impacts.

Through these narratives, we found that landowner acceptability of Kentucky bluegrass varies according to the stages of invasion. At early stages of invasion, characterized by enhanced forage quality and yield in the spring without any change to other ecosystem services, it is expected to be slightly acceptable to landowners. At moderate stages of invasion, characterized by a moderate loss in grass diversity along with increased forage quality, quantity, and spring availability, landowners are expected to view these impacts as neutral to slightly acceptable. However, at the late stages of invasion, characterized by enhanced forage quality and quantity in the spring,

3 yearlings at the NGPRL surrounded by predominant Kentucky bluegrass, wheatgrass and smooth brome.

reduction of forage in the summer, and a large reduction in the diversity of other grasses as well as reductions in floral resources and grassland bird diversity, Kentucky bluegrass is expected to be slightly unacceptable to landowners.

We found that landowners prefer increases to ecosystem services that directly impact their operation, such as forage and water, with less focus on increasing indirect services such as biodiversity and pollination. The degree to which a landowner is actively engaged in management was related to increased sensitivity to invasion. Based on this relationship, landowners are likely to attempt to control bluegrass only once the invasion is advanced, at which point it is also harder to control.

Kentucky bluegrass herbarium sample card

Rajala, K., Sorice, M. S., Toledo D. 2021. Gatekeepers transformation: private landowners evaluate invasives based on impacts to ecosystem services. Ecosphere 12(7).

Sorice, M. G., Rajala, K., Toledo, D. 2022. Private landowners and the facilitation of an invasive species. Rangelands 44(5): 345-352.

Rapid formation of abiotic CO2 in agricultural soils

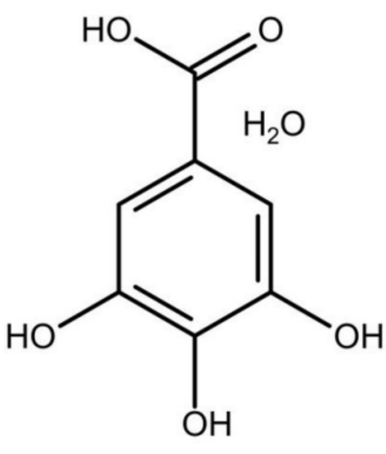
Jonathan Halvorson, Virginia Jin, Mark Liebig, Roberto Luciano, Ann Hagerman, and Michael Schmidt

This study shows that abiotic chemical reactions between some organic compounds and metal oxides may be significant sources of CO2 from agricultural land. Understanding this process is important for understanding the global carbon cycle.

Core ideas

- Adding gallic acid, an organic compound produced by plants, to soil produced a rapid abiotic burst of CO2 unrelated to carbonates
- The amount of CO2 produced varied with management and soil type
- Similar patterns resulted when gallic acid was mixed with Manganese oxide
- Such reactions may occur between root discharge and soil metal oxides
- With repeated redox cycling, this process might be a significant contributor to carbon emissions from soil

Carbon dioxide (CO2) may be emitted from the soil due to many processes. These include biological and chemical processes, including abiotic chemical reactions between organic compounds and metal oxides (redox).



Gallic acid or 3,4,5-trihydroxybenzoic acid monohydrate

K30 CO2 sensor affixed to the inner lid of a 950 mL jar with data acquisition via computer.

However, little is known about how this reaction might vary with management or among different soil types. This study measured the CO2 that rapidly formed during incubations of soil samples from different crop rotations, archived soils from across the U.S., and from purified metal oxides. The samples were treated with several different solutions including Gallic acid (GA).

Soils treated with GA quickly produced CO2. A 5-year crop rotation responded less than soils from other rotations or from pasture. Samples from other sites produced a wide range of responses, but the CO2 from some soils was attributable to the acidity of the GA treatment. Results not attributable to acidity were likely due to reactions between GA and Mn oxide in the soil.

Since GA is commonly produced by plant roots, this study suggests that these types of reactions may be significant sources of CO2 emissions from agricultural land. Further work is needed to characterize the magnitude and distribution abiotic redox-related CO2 emissions from agricultural lands.

Conservation Research Program research: Increasing establishment success.

By John Hendrickson

Since the Conservation Reserve Program (CRP) was signed into law in 1985, it has evolved beyond ensuring perennial cover on erodible land. Other potential benefits of the CRP program, such as improved pollinator habitat, have resulted in more diverse species mixtures, including many flowering plants, being recommended for use in CRP plantings.

Plantings that have included more flowering plants or forbs, have not been as successful as plantings that had a greater proportion of grasses. This was especially true in drier regions of the United States where establishing perennial vegetation can be especially difficult. The USDA-Farm Service Agency (FSA) recognized the need for additional research into establishing diverse CRP plantings in arid and semi-arid sites (<10 and 10-15 inches of annual precipitation) and reached out to Agricultural Research Service (ARS) for help to develop new establishment strategies.

1Seed mix in the drill intermixing the varieties of seeds with cracked corn for distribution.

Holly Johnson watching to be sure that seed mix continues to flow through the drill.

ARS locations in Mandan ND, Sidney MT, Fort Collins CO, and Logan UT were involved in the first phase of the project which focused on alternative seedbed preparation and seeding techniques to improve pollinator plant establishment. Research on sites in the northern Great Plains, located in Havre, Sidney, and Froid, MT, was conducted by researchers in Mandan and Sidney. Treatments at these sites ranged from Prevailing Practice which used seedbed preparation and seed materials recommended by USDA-NRCS to Aspirational treatments that included the use of cover crops, alternative row seeding, and an enhanced seed mixture.

While perennial establishment success was not good in any treatment, the Alternative" treatment did result in greater establishment of pollinator plants than the other treatments. In addition, there was a strong year effect which suggests we need to learn more about how environmental conditions before, during, and after seeding impact establishment. A constant among all the regions

(MT, CO and UT) was the negative impact of weeds on establishing CRP plants.

The first phase of the project will be completed in 2023; however, FSA provided additional funding to expand on this research. In phase 2 of the project, all the initial locations plus ARS scientists in Miles City MT, Davis CA, and researchers at Colorado State University are planning to evaluate the effect of 1 versus 2 years of weed control plus different seeding rates to control weeds.

This research, scheduled to start in 2024, is based on observations from the first phase of the CRP project and will also include region-specific treatments. This phase will also use expertise at the ARS locations in Sidney and Davis to evaluate floral quality in CRP seedings.

In 2022, FSA also provided additional funding for a third phase of the project to focus on targeted herbicides, plant traits, residue and nutrient management, and weather and soil moisture forecasting to develop a decision support tool. The end goal is to identify management strategies and species-selection guidelines for successful CRP pollinator establishment in semi-arid regions.

The Havre, Montana alternative site showing blanket flower, yellow cornflower, and Canada milkvetch.

NGPRL Research Bibliography

This bibliography is meant to function as a resource for a range of audiences who have diverse purposes. This bibliography is meant to be scannable. The primary impact information is, most often, located within the first paragraph or two; this area will often include both results and implications from the published paper. For those readers who have more than a cursory interest, the entire annotation mostly includes specifics and details from the publishing project.

This bibliography is meant to be comprehensive for 2022, including trade publications, peer reviewed journals, and conference presentations.

These annotations are not intended to replace the scientific information in the publications. While the summaries are intended to authentically represent the work, it is not always possible to capture the full original intent. For researchers intending to cite, the link to the articles is present and can be accessed for those seeking additional or more scientific context. Citations are in modified APA style and presented in chronological order according to publication date. The PDF version of this 2022 Results report has active links directly to the complete source.

2022 Trade Publications

Review highlights soil archive use for research

Mark Liebig & Emma Bergh. (March 2022). Review highlights soil archive use for research. *CSA News*, 67(4).
https://doi.org/10.1002/csan.20698

Archived soil samples provide a snapshot of soil properties at the time and place they were collected, allowing researchers to revisit past conditions and assess change over time. This historical information is key to assessing the sustainability of land management practices.

Despite the recognized importance of soil archives, their use for research purposes is poorly understood. In the March/April issue of Soil Science Society of America Journal, researchers report findings from a compilation of 245 publications with documented use of soil archives. The team found increasing use of soil archives for research since 1980, peaking at 59 publications between 2016 and 2020. Soil archive age across the compilation ranged from 5 to 160 years, with a mean of 48 years. The compilation also highlighted the most common use of soil archives, namely, investigations of soil organic matter change in cropland in developed countries.

As such, significant land-use and geographical gaps exist when it comes to understanding long-term soil change worldwide. Major gaps in knowledge happened to be in regions where soil resource use is projected to intensify in the coming decades. Increased coordination among researchers, coupled with enduring investments in the curation and retention of soil archives, are recommended.

Increased coordination among researchers coupled with enduring investments in the curation and retention of soil archives can preserve this useful long-term resource.

Using total digestible nutrients for grazing management

Rachael Christensen, **John Hendrickson**, & **David Toledo**. Using total digestible nutrients for grazing management. *Forage Focus*, 3/1/2022.

Efficient use of cattle grazing resources requires matching animals' needs to the forage growth cycle. When evaluating a grazing/feeding program, total digestible nutrients (TDN) can be a helpful tool for preventing severe nutrient shortage, but TDN has inadequacies. It tends to overestimate feed and forage energy. Challenges of achieving a low-cost feeding program include matching the time frame of highest animal forage TDN requirements to coincide with highest available pasture nutrients. During times of low forage availability, TDN is used to determine if hay, dormant, or stockpiled grass meets energy needs. When forage TDN is not sufficient, comparing the TDN of hay and supplements is a way to keep costs down by limiting overfeeding purchased feed sources. Most commercial labs predict TDN of samples using chemical analysis to determine acid detergent fiber (ADF) content.

Keep in mind, TDN is just one piece of information, as animals have other nutritional needs including protein, minerals, and fat. In the northern Great Plains, Kentucky Bluegrass (KBG) has invaded the native ranges and is often 70-80% of rangeland and pasture. In the table, TDN predicted from 3 years of chemical analysis of KBG dominated pasture is presented, as well as TDN for 4 years of alfalfa (ALF) hay harvested for various research projects. TDN required each month for a lactating beef cow calving in late April with a cow at her side is also presented. Most months the base forage may meet the needs of lactating cows; however, in June there is a chance cow nutrient needs might not be fully met if forage digestibility is less than predicted or her time budget does not allow enough intake. It may be warranted to supplement with hay such as that presented here to meet production goals. A grazing alfalfa stand could also serve to supplement the low grass TDN. Having TDN information helps farmers make decisions to ensure cattle nutrients needs are met.

	KBG provided TDN	Alfalfa provided TDN	Lactating beef cow TDN requirements
May	65.5	n/a	59.6
June	61.9	64.5	60.9
July	60.5	66.3	58.6
Aug	59.8	58.0	57.0

2022 Published Reviews

Reviews offer a broader sense on what is happening within a particular field, often surrounding a particular idea or concept. A review provides a synthesis of information that can offer valuable context to a range of readers and researchers.

In science, reviews are essential to identifying, building, and sharing trends, patterns, and ideas. These reviews can help gather information on trends (think, "carbon") or identify relationships to a larger body of research and publishing.

For NGPRL stakeholders, a review article might add additional and expansive context. A review will include both a summary of key sources and synthesize the ideas between the research.

A review of unmanned aerial vehicle based methods for plant stand count evaluation in row crops.

Harsh Pathak, **Igathinathane Cannayen**, Zhao Zhang, **David Archer**, & **John Hendrickson.** (5/25/2022). A review of unmanned aerial vehicle based methods for plant stand count evaluation in row crops. *Computers and Electronics in Agriculture*. 198, 107064.

https://doi.org/10.1016/j.compag.2022.107064

This review will be helpful to farmers, producers, and researchers in selecting and employing the UAV algorithms for evaluating plant stand count.

Plant stand count helps in estimating the yield and evaluating the planting efficiency and seed quality. Traditional methods of counting by manual measurement are time consuming, laborious, and error prone and ground-based sensing methods are limited to smaller spaces. High spatial resolution images obtained from unmanned aerial vehicles (UAV) can be used in conjunction with computer vision algorithms to evaluate plant stand count, as it directly influences the yield.

Despite the importance of high-throughput plant stand count in row crop agriculture, no synthesized information is available. Therefore, the objective of this paper was to review the current studies that focus on evaluating plant stand count using UAV imagery to provide well-synthesized information, identify research gaps, and provide some recommendations. In this study, a comprehensive literature search was performed on three academic databases (Agricola, Web of Science, and Scopus), and a total of 29 articles were found based on search terms and selection criteria for review.

This review shows that:

- appropriate stage after plant emergence without canopy overlap is necessary for image acquisition;
- optimal flying height should be selected to balance the field coverage and accuracy;
- L*a*b* color space can provide better segmentation;
- hyperspectral camera imagery can provide good discrimination;
- deep learning with data augmentation and transfer learning models can be used to reduce the computational time and resources;
- the stand count methodology that has been successful with corn and cotton could be extended to other row crops and horticultural crops; and
- application of direct image processing and use of open-source platforms is required for stakeholder participation.

Potential benefits of tanniferous forages in integrative crop-livestock agroecosystems.

Andrea Clemensen, **Jonathan Halvorson**, **Rachael Christensen**, & **Scott Kronberg**. (7/22/2022). Potential benefits of tanniferous forages in integrative crop-livestock agroecosystems. *Frontiers in Agronomy*, 4.

https://doi.org/10.3389/fagro.2022.911014

Tannins are produced by plants and can potentially benefit agriculture and the environment. However, only recently have there been attempts to address their benefits to soil, crops, and animals.

In this brief review, we examine the literature as it shows how tannins influence soil microbial dynamics and nutrient cycling, the function of tannins in forages, and the role tannins have in improving the health of foraging animals. We also examine speculation on potential advantages for human health from consumption of animal-based foods from animals that consumed tanniferous forages or supplemental plant materials

The review is useful to researchers and producers in understanding how integrating plants that contain tannins into crop-livestock systems may make agriculture more sustainable.

2022 Dataset Published

One of the most important values that a storied research center like the NGPRL in Mandan has been a long history with a lot of information. The many ongoing studies with the many collaborators offer significant research and has yielded an enormous amount of data. Data that can propel research on a local and a global scale if it is shared properly, such as the database published in 2022.

While this database might not be immediately usable for many audiences, database publication can lead to new and important discoveries that are unimaginable to the original authors. Ingenuity and new applications through data integration will transform the way information is used.

Data from conservation practices induce tradeoffs in soil function: Observations from the Northern Great Plains'

Mark Liebig, Veronica Acosta Martinez, **David Archer**, Jonathan Halvorson, **John Hendrickson**, **Scott Kronberg**, Susan Samson-Liebig, & Jennifer Vetter. (19 Oct 2022). Data from conservation practices induce tradeoffs in soil function: observations from the Northern Great Plains'. *Ag Data Commons*.

https://doi.org/10.15482/USDA.ADC/1528105

Cropland expansion and reduced crop rotation diversity throughout the northern Great Plains has negatively impacted soil quality, creating a need to identify conservation practices that can counteract this trend.

A study was conducted to quantify soil property responses to crop diversity/intensity, cover crops, and livestock integration under controlled experimental conditions, and land use (dryland cropping, native grassland, untilled pasture) on working farms and ranches, all on a common soil type in southcentral North Dakota, USA. Data from this study included near-surface (0-5 cm) measurements of soil physical, chemical, and biological properties over a 3-yr period for contrasting long-term experimental treatments at the USDA-ARS Northern Great Plains Research Laboratory, Mandan, North Dakota.

Soil profile (0-100 cm) assessments of soil physical and chemical properties complemented near-surface measurements. Data were used to generate soil quality index scores using the Soil Management Assessment Framework. Annual spring wheat grain yields for experimental treatments complemented soils data. Similar evaluations were conducted on six on-farm sites in Emmons County, North Dakota, USA, but only for one year and without grain yield data.

Data may be used to better understand soil property responses to cropland conservation practices and different land uses. Data are generally applicable to rainfed conditions under a semiarid Continental climate for Temvik-Wilton silt loams (fine silty, mixed, superactive, frigid Typic and Pachic Haplustolls) and associated soil types (i.e., Grassna, Linton, Mandan, and Williams).

2022 Peer Reviewed Publications

Peer reviewed journals are publications that apply a thorough evaluation process through which other experts examine the quality and merit of the research. Often generally referred to as "scholarly sources" the information is most often presented in scientific jargon, IMRD organization, and offers complex comprehensive data presentation.

These summaries are meant to be accessible and scannable.

- **For core concepts and impact, read the first couple paragraphs.**
- **For method and detailed results, read the entire summary.**
- **For deep and complex details about the science, the method, the contributing literature, the link will bring you to the full publication.**

If you have issues accessing and article, reach out to Seth.Archer@usda.gov. He will help you get the information you are looking for.

These summaries are presented in chronological order, based on acceptance dates.

The citation style is a modified APA with names of NGPRL scientists in bold face font.

Nature, nurture, and vegetation management: Studies with sheep and goats.

John Walker & **Scott Kronberg**. (1 Jan 2022). Nature, nurture, and vegetation management: Studies with sheep and goats. *Animal - The International Journal of Animal Biosciences*, *16*(1), e100434.

https://doi.org/10.1016/j.animal.2021.100434

Introducing targeted grazing through rearing sheep and goats can help reduce invasive species in an economic and environmentally sustainable way.

Invasive plants are a global problem that have a multibillion-dollar impact in the U.S. Many problem plant species such as the noxious leafy spurge contain toxins that cause livestock to avoid grazing them and give problem plants a competitive advantage over more palatable plants.

Targeted grazing by livestock is an environmentally sustainable and effective method to reduce the abundance of invasive plants. The effectiveness of targeted grazing as a control method is dependent upon animals' preference for eating a problem plant species and defoliating it relative to common desirable plant species to place the targeted species at a competitive disadvantage (plants compete for nutrients and sunlight).

Foraging preferences for plant species are determined by genetic and environmental factors. To enhance the effectiveness of targeted grazing, livestock species like goats and sheep with the greatest innate preference for the target plant species should be raised in an environment that provides experience grazing the target plant at a young age.

Conservation practices induce tradeoffs in soil function: Observations from the northern Great Plains

Mark Liebig, Veronica Acosta Martinez, **David Archer**, **Jonathan Halvorson**, **John Hendrickson**, **Scott Kronberg**, Susan Samson-Liebig, & Jennifer Vetter. (16 Feb 2022). Conservation practices induce tradeoffs in soil function: Observations from the northern Great Plains. *Soil Science Society of America Journal*, *86*(6), pp. 1413-1430.

https://doi.org/10.1002/saj2.20375

This study suggests that the use of perennial agricultural systems and adoption of diverse, nutrient-efficient dryland cropping practices should be prioritized to enhance soil health in the northern Great Plains.

Dryland cropping occupies nearly 200,000 square miles within the northern Great Plains. Over the past 30 years, the region has experienced significant grassland conversion to cropland coupled with a transition away from small grain cropping systems toward systems increasingly dominated by corn and soybean. Cropland expansion and reduced crop rotation diversity in the region has negatively impacted soil health, creating a need to identify conservation practices that can counteract this trend.

A three-year study was conducted to examine soil health responses to crop diversity/intensity, cover crops, livestock integration under controlled conditions, and land use (dryland cropping, native grassland, untilled pasture) on working farms and ranches. This study was performed on a common soil type in southcentral North Dakota (fine-silty, mixed, superactive, frigid Typic and Pachic Haplustolls).

Among dryland cropping practices, diverse, continuous cropping led to improvements in soil structure, nutrient supply potential, and biological habitat, but increased soil acidification and soil nitrate accumulation. Cover crops had a negligible effect on the soil, while livestock integration on cropland improved nutrient supply potential and biological habitat, but impaired infiltration. Relative to dryland cropping, soil health was consistently improved under perennial systems.

Cover crop interseeding effects on aboveground biomass and corn grain yield in western North Dakota

Eric Antosh, **Mark Liebig**, **David Archer**, & Roberto Luciano. (17 Feb 2022). *Crop, Forage & Turfgrass Management*, *8*(1), e20148.

https://doi.org/10.1002/cft2.20148

Early planting of intercropping systems in western North Dakota is an effective way to generate more biomass and protect soil from erosion without negatively impacting grain yield from the primary crop.

Cover crops can provide many benefits, but the short growing season and variable weather in the northern Great Plains makes it difficult to include them in cropping systems. Relay intercropping – planting cover crops into standing grain crops – could be a way to successfully grow cover crops in this region. Relay intercropping has been used in wetter areas of North Dakota, but it has not been tested in the western part of the state where conditions are typically drier.

A 3-year study was conducted on the Area 4 SCD Cooperative Research Farm near Mandan, ND to find out the best time to intercrop cover crops in corn. Study treatments included a crop with no cover crop and cover crops planted at advancing corn growth stages. Across the three years, aboveground biomass was greatest in the 1st planting (393 lb/ac), least in the control and 3rd planting (Mean=212 lb/ac), and intermediate in the 2nd planting (247 lb/ac).

Cover crop treatments had no significant effect on corn grain yield in any year, suggesting that intercropping cover crops in corn will not reduce corn yield under conditions like those observed in this study. Limited competition from cover crops and weeds likely contributed to this outcome, as cover crop production was low. Future intercropping research in western North Dakota should consider the forage value of the cover crops, winter survival of different cover crops, and row spacing effects on biomass production and crop yield.

Nitrogen bound to manure fiber is increased by applications of simple phenolic acids

Jonathan Halvorson, **Scott Kronberg**, **Rachael Christensen**, Ann Hagerman, & **David Archer.** (22 Feb 2022). Nitrogen bound to manure fiber is increased by applications of simple phenolic acids. CABI Agriculture and Bioscience (CABI A&B). 3:11.

https://doi.org/10.1186/s43170-022-00078-7

When livestock consume plants rich in plant secondary compounds (PSM), such as tannins, livestock feces contain more nitrogen and may possess a higher concentration of nitrogen fixed to insoluble manure fiber than when the animals consume low PSM feeds. A seemingly similar phenomenon occurs when some PSM are added to soils where it is likely that the PSM facilitate binding interactions between nitrogenous compounds and the soil.

We hypothesized that simple PSM, such as phenolic acids, could increase ADF-N by reaction with manure in the absence of biological activation such as rumen digestion. In our first experiment we applied different concentrations of phenolic acids to dried pulverized manure and measured changes to ADF-N. Patterns of ADF-N were affected by complex but inconsistent relationships between treatment compounds and solution concentration. Further, we found little distinction between the treatment means and samples treated with only water. A second experiment featured more treatment compounds applied at a single concentration and added a nitrogen factor. Results showed ADF-N was not affected by treatment with water, benzoic or gallic acid when compared to untreated manure but was significantly increased by the other treatments.

These studies suggest organic nitrogen in manure can change with interactions with manure fiber. So, some changes to manure composition associated with tannins or other compounds do not depend on digestion. The amount of nitrogen bound to manure fibers may affect nutrient cycling.

How profitable is switchgrass in Illinois, USA? An economic definition of Marginal land

Nictor Namoi, **David Archer**, Todd S. Rosenstock, Chunhwa Jang, Cheng-Hsien Lin, Arvid Boe, DoKyoung Lee. (16 April 2022). How profitable is switchgrass in Illinois, USA? An economic definition of marginal land. Grassland Research 1, pp. 111-122.

https://doi.org/10.1002/glr2.12017

Decisions regarding the conversion of land from an existing crop to bioenergy crops are critical for the sustainable production of both food and fuels. This study seeks to establish criteria for delineating land as “economically marginal”, and thus suited for growing switchgrass.

In this case study of an Illinois agricultural field, the profitability of switchgrass was compared to corn and soybean crop prices. Further, the study also evaluates the profitability of switchgrass when replacing corn-based yield estimates from the Soil Productivity Index (SPI) of Illinois.

Based on a dry-matter yield of 10.45 Mg ha^{-1}, switchgrass can compete with soybeans only at the high price of \$88 Mg^{-1}, but depending on location, can compete with corn at \$66 Mg^{-1}. Across Illinois, at \$88 ha^{-1}, all Illinois land with SPI < 100% and 95% of land under SPI class C (SPI 100–116) is profitable under switchgrass. Switchgrass may not be profitable relative to corn grown in the SPI class A (SPI > 133) and only 7% of class B (SPI 117–132).

Our results show that land with drainage and erosion limitations is economically marginal when corn and soybean yields are low, and the farmgate price for switchgrass is greater than \$66 Mg^{-1}. However, this may not be possible on land where switchgrass is replacing frequent soybean rotations (corn–soybean ratio ≤ 1). Land used to produce only soybeans may only be marginal at the farmgate price of \$88 Mg^{-1}.

Further studies need to be conducted to identify how much land can be converted to switchgrass without harming corn production.

Field measurement of wind erosion flux and soil erodibility factors as affected by tillage and seasonal drought

Stephen Merrill, Teddy Zobeck, & **Mark Liebig**. (20 Apr 2022). Field measurement of wind erosion flux and soil erodibility factors as affected by tillage and seasonal drought. *Soil Science Society of America Journal*, *86*(5), pp. 1-16.

https://doi.org/10.1002/saj2.20436

The practice of no till management and continuous plant and residue coverage is critical for preventing soil losses from wind erosion in semiarid agriculture conditions.

Core concepts from the study:

- Wind erosion loss was two- to six times greater under disk tillage than no till.
- Seasonal drought resulted in two- to fivefold greater wind erosion loss.
- Residue coverage offers the greatest resistance to erosion.

Tillage increases wind erosion risk by destroying crop residues and surface soil aggregation. Also, drought can greatly accelerate wind erosion by reducing plant growth and decreasing ground cover. Field measurements documenting the interaction of tillage and drought on wind erosion in cropland have not been reported in the literature.

To address this knowledge gap, a multi-year study was conducted near Mandan to measure wind erosion in response to three levels of tillage during a seasonal drought. Following a single tillage event on fallowed soil, wind erosion was increased with increasing levels of disturbance by tillage.

Wind erosion was 2- to 5-fold greater during a year when July and August precipitation was less than 30% of the long-term average, resulting in lower residue coverage. Residue coverage under no-till during this period was retained, resulting in less soil loss. Field measurements from this study showed that the residue-destroying effects of a single tillage event can intensify soil loss by wind erosion on cropland in the semiarid northern Great Plains.

How do tanniferous forages influence soil processes in forage cropping systems?

Andrea Clemensen, Juan Villalba, Stephen Lee, Frederick Provenza, Sara Duke, & Jennifer Reeve. (26 April 2022). How do tanniferous forages influence soil processes in forage cropping systems? *Crop, Forage & Turfgrass Management*, *8*(1), e20166.

https://doi.org/10.1002/cft2.20166

Nitrogen fixing crops such as alfalfa and sainfoin may benefit agricultural systems in several ways. Planting nitrogen fixing plants such as alfalfa and sainfoin in forage cropping systems reduces needs for nitrogen fertilizers, and including tanniferous forages may reduce nitrogen losses, enhancing the economic viability and the sustainability of agricultural systems.

Core ideas:

- Plant secondary metabolites influence soil dynamics.
- Soil nitrate was greater in alfalfa than in sainfoin
- Tannins from sainfoin may influence soil nitrogen cycling in forage cropping systems

In addition to quality forage, both alfalfa and sainfoin contain plant secondary metabolites that play important roles in agricultural systems. Alfalfa contains triterpenes (saponins), and sainfoin contains phenolic compounds (tannins). These plant secondary metabolites can change the way nutrients are cycled in the soil. This area of research has mostly been done in forest systems, or in controlled laboratory settings. So, research is needed in agricultural systems.

This field study occurred in Lewiston, Utah, comparing alfalfa and sainfoin with tall fescue. Our study included a fertilized bale and remove system, a green manure system (leaving plant residue in field), and a no-fertilizer bale and remove system comparing alfalfa and sainfoin with tall fescue.

Green manure plots had more soil organic carbon, greater soil enzyme activity, and greater soil microbial biomass than the other management systems. Dehydrogenase enzyme activity is an indicator of overall soil microbial activity, which may be used to gauge soil health. Plant biomass was greater in sainfoin than in alfalfa, while soil nitrate was greater in alfalfa than in sainfoin plots. Lower soil nitrate in sainfoin plots could be due to the condensed tannins, which can slow down nitrogen mineralization. Planting forages, like sainfoin, that contain tannins may reduce nitrogen loss, and ultimately enhance agricultural sustainability.

Rotating perennial forages into annual wheat cropping systems: Correlations between plant available soil and grain mineral concentrations

Andrea Clemensen, Michael Grusak, Sara Duke, Jose Franco Jr., **Mark Liebig**, **John Hendrickson**, & **David Archer**. (29 Apr 2022). Rotating perennial forages into annual wheat cropping systems: Correlations between plant available soil and grain mineral concentrations. *Agrosystems, Geosciences & Environment*, *5*(3), e20281.

https://doi.org/10.1002/agg2.20281

This study revealed that integrating perennial forage phases into wheat cropping systems increases wheat yield and protein but may deplete some available soil minerals. This is important information to know for producers to increase yield and determine fertilizer application decisions.

Core ideas·

- Mineral associations between soil and wheat grain were assessed
- Grain zinc diminished where calcium soil concentrations were higher
- Grain boron, magnesium, manganese, and sulfur increased when these minerals had higher concentrations in soil
- Plant available iron, manganese, phosphorus, sulfur, and zinc concentrations reduced under perennial forages

Different land management techniques may influence both soil and crop quality. However, few studies examine linkages between land management and soil or crop quality.

We analyzed soil and wheat grain samples in a dryland cropping study in the northern Great Plains conducted from 2006-2011. We looked at wheat yield, test weight, and protein concentration, and linkages between 11 plant available soil mineral concentrations and 11 wheat grain mineral concentrations following five years of perennial forages compared to a continuous spring wheat system.

The perennial forage treatments were either alfalfa, intermediate wheatgrass, or an alfalfa intermediate wheatgrass mixture. Wheat following five years of alfalfa had greater yield, test weight, and protein, yet lower grain Zn concentration. As plant available soil B, Mg, Mn, and S concentrations increased, wheat grain mineral B, Mg, Mn, and S concentration increased. Interestingly, when plant available soil Zn and Ca concentrations increased, the wheat grain Zn and Ca concentrations decreased.

Our study shows that integrating perennial forage phases into wheat cropping systems increases wheat yield and protein but may deplete some plant available soil minerals. However, lower plant available mineral concentrations do not always cause grain mineral concentration to be lower. Although incorporating perennials into annual cropping systems can benefit some soil quality parameters it may also deplete plant available soil minerals. This information is useful to producers in improving wheat yield and nutrient concentrations and in making fertilizer application decisions.

Carbon fluxes from a spring wheat-corn-soybean crop rotation under no-tillage management

Mark Liebig, Nicanor Saliendra, & **David Archer**. (29 June 2022). Carbon fluxes from a Spring wheat-corn-soybean crop rotation under no-tillage management. *Agrosystems*, *Geosciences & Environment*, *5*(3), e20291.

https://doi.org/10.1002/agg2.20291

This study suggests that a spring wheat – corn – soybean rotation, under no till management, results in a carbon loss from the soil into the atmosphere. Mitigation of this carbon movement may be achieved from the use of cover crops, resulting in more stable soil biology and a more functioning soil that can withstand various stressors.

Core Ideas

- Special methods were used to quantify carbon dioxide movement within a wheat–corn–soybean rotation
- Annual net ecosystem production of carbon dioxide was negative for wheat, positive for corn, and near zero for soybean
- Carbon removed in grain was less than a third of carbon lost by soil respiration
- The carbon balance from the soil for the rotation was negative, implying carbon loss

Corn and soybean are increasingly grown in the northern Great Plains. How these two crops affect the carbon balance of agricultural land in the region is not well known.

A 3-year study was conducted to quantify the carbon balance of a spring wheat-corn-soybean rotation under no till management. Two field sites with the same soil type near Mandan, ND were used for the study.

After accounting for carbon removed in grain, the carbon balance in the soil was negative for the 3-year rotation, suggesting that more carbon was lost from the site than was taken up by the plants. Some ways to reduce carbon loss may include growing cover crops, changing the types of crops grown, extending the length of the crop rotation, or intercropping (i.e., growing two crops at the same time).

Heterogeneity of Kentucky bluegrass seed germination after controlled burning

Jonathan Halvorson, **David Toledo**, & **John Hendrickson**. (01 July 2022). Heterogeneity of Kentucky Bluegrass seed germination after controlled burning. *Rangeland Ecology and Management*, *83*(1), pp. 112-116.

https://doi.org/10.1016/j.rama.2022.04.001

This study indicates that exposure to prescribed burning killed many Kentucky Bluegrass seeds located near the soil surface, supporting the idea of prescribed burning to control spread in invaded grazing lands. However, smaller locations that may support or protect the seeds (e.g., standing litter or dry thatch) should be identified, evaluated, and managed when removing Kentucky Bluegrass or establishing native species for foraging.

Fire is sometimes advocated as a means for controlling Kentucky bluegrass (KBG) in invaded grazing lands. Still, little is known about the effects of fire on KBG seed survival. We placed seeds of KBG in shallow metal dishes at ground level, and exposed them to fire while monitoring temperature at the soil surface and at 10 cm. We then measured subsequent seed germination.

Seed germination from burned plots was significantly lower than unburned control dishes. Germination success was similar in areas previously managed with both grazing and fire and plots previously managed by fire alone. Maximum surface temperatures during the test burns averaged 271 degrees Celsius but varied widely while maximum temperature at 10 cm above the soil surface was slightly higher at 301. Seed germination decreased with increasing soil temperature measured during the burn.

However, seed survival often was quite different between sample dishes that were close to each other. Such extreme variability may result from unburned areas remaining after the fire that acted as safe sites for seeds. This study indicates that fires kill KBG seeds at the soil surface. However, use of fire to reduce viable seeds must be evaluated carefully since while fire may kill existing stocks, it may also induce subsequent seed production.

Patterns of seedling emergence from North Dakota grazing lands invaded by Kentucky bluegrass

Jonathan Halvorson, **John Hendrickson**, & **David Toledo**. (08 July 2022). Patterns of seedling emergence from North Dakota grazing lands invaded by Kentucky bluegrass. *Rangeland Ecology and Management*, *84*(1), pp. 126-133.

https://doi.org/10.1016/j.rama.2022.07.003

This study is useful to grassland managers and researchers in identifying how seeds are distributed in and near the soil surface. Understanding this seed distribution, primarily prevalent in litter, will contribute to ongoing development of effective Kentucky bluegrass management strategies.

Kentucky bluegrass is an important invasive grass in the northern Great Plains, but little is known about its impact on plant seeds in and near the surface of the soil. To better understand this impact, this study measured seedling appearance in different layers, grass litter, thatch, and mineral soil, collected from grazing lands near Mandan, ND.

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Many more seedlings and, in particular, more Kentucky bluegrass emerged from litter material, than the other layers. Plots of the number of seedling species for the layers demonstrated a common pattern; a single main species, several more species with low abundance and most species represented by very few individuals.

Kentucky bluegrass was the most prevalent species accounting for 94.3%, 71.9%, and 69.9% of seedlings that emerged from litter, thatch, and soil layers, respectively. These plots also indicated that while there were fewer species represented in soil compared to litter, their numbers were more evenly distributed

How modelers model: The overlooked social and human dimensions in model intercomparison studies

Fabrizio Albanito, David Mcbey, Pete Smith, Fiona Ehrhardt, Matthew Harrison, Arit Bhatia, Gianni Bellocchi, Lorenzo Brilli, Marco Carozzi, Karen Christie, **Mark Liebig**. (02 Sept 2022). How modelers model: The overlooked social and human dimensions in model intercomparison studies. Environmental Science and Technology, 56(18), pp. 13485–13798.

https://doi.org/10.1021/acs.est.2c02023

Analyzing results from multiple models has been used to research greenhouse gas emissions from agriculture and to develop mitigation options. Running different models and model versions with different sets of site conditions is a way to account for the uncertainty derived from single model simulations.

However, differences in model limitations and how input data are treated make model comparisons difficult. Additionally, the complexity of model ensemble studies arises not only due to the models themselves, but also on the experience and approach used by the modelers to calibrate and validate results. There is little information on the choices made during model calibration, how many parameters are calibrated relative to the data available, and how models are validated when their outputs are compared against observed data.

Given these concerns, modelers that contributed to a recent model ensemble study were surveyed. We analyzed the rationale used by the modelers where different model types were compared across five stages. Two conclusions were derived from this investigation: 1) modelers perceive datasets such as general site information, climate condition, and management practices as very important for modelling cropland and grassland systems, and 2) the framework of multi-model intercomparison studies needs to pay more attention to the structure of the models, while understanding interrelationships between different processes in the models. Moving forward, ensemble studies should include in their guidelines a quantified understanding of how data interpretations and model structures influence calibration and validation strategies.

2022 Formal Presentations

Formal presentations are the way research is done in real time, not waiting for a reviewer from a peer reviewed journal to offer feedback for publication. As researchers, we gather share and discuss ongoing work. In this way, the community of researchers can offer insight into problems or benefits of an ongoing project. We learn from each other, and we develop networks to share data, samples, and ideas.

Conference presentations are ongoing science happening in real time processes.

Can defoliation reduce the abundance of smooth brome? An examination of phenology and defoliation timing

John Hendrickson, **Andrew Carrlson**, Aaron Field, **Andrea Clemensen**, & Vanessa Yeoman. (06 Feb 2022). Can defoliation reduce the abundance of smooth brome? An examination of phenology and defoliation timing.

Mapping North America agroecosystems: A social-ecological systems approach.

Zachary Hurst, **David Archer**, Alisa Coffin, Tiffany Van Huysen, Sarah Goslee, Kathryn Pisarello, J.D. Wulfhorst, Sheri Spiegal, (2022.) Mapping North America agroecosystems: A social-ecological systems approach. Presentation at Agriculture and Human Values.

Economic risk and returns of harvesting or grazing biomass in northern Great Plains cropping systems.

David Archer, **Mark Liebig**, & **Scott Kronberg**. (2022). Economic risk and returns of harvesting or grazing biomass in northern Great Plains cropping systems. Presentation as a poster at the ASA-CSSA-SSSA Annual Meeting, Baltimore, MD, 6-9 Nov. 2022

Integrated crop-livestock systems research at the Northern Great Plains research laboratory

Mark Liebig, **David Archer**, **John Hendrickson**, **Scott Kronberg**, & **Rachel Christiansen**. Integrated crop-livestock systems research at the Northern Great Plains research laboratory. Presented at 'Soil Health Workshop: Integrated Systems, Intercropping, and Organic Matter Management', NDSU Dickinson Research Extension Center, Dickinson. September 14, 2022.

Drought effects on carbon and water fluxes for a spring wheat-corn-soybean rotation in North Dakota

Nicanor Saliendra, Craig Whippo, David Archer, & **Mark Liebig**. Drought effects on carbon and water fluxes for a spring wheat-corn-soybean rotation in North Dakota. Presentation as a poster at the ASA-CSSA-SSSA Annual Meeting, Baltimore, MD, 6-9 Nov. 2022

Influence of drought on spring wheat yield: Differences between cultivars

Andrea Clemensen, John Hendrickson, & **David Archer**. Influence of drought on spring wheat yield – differences between cultivars. Presentation at 2022 ASA, CSSA, SSSA International Annual Meeting, Baltimore, Maryland, November 6-9

Influence of previous soil management strategies on perennial forage establishment

John Hendrickson Mark Liebig, Rachel Christensen, David Archer, Jonathan Halvorson, & Andrea Clemensen. Influence of previous soil management strategies on perennial forage establishment. Presentation at 2022 ASA, CSSA, SSSA International Annual Meeting, Baltimore, Maryland, November 6-9

Variation in methodology obscures clarity of global warming potential estimates

Mark Liebig & Emma Lottie. Variation in methodology obscures clarity of global warming potential estimates. Virtual Presentation at 2022 ASA, CSSA, SSSA International Annual Meeting, Baltimore, Maryland, November 6-9

Agroecoregions resulting from novel clustering methods: Production variables

Chandra Holifield Collins, Claire Baffaut, A. Bean, Patrick Clark, Alisa Coffin, Sarah Goslee. **John Hendrickson**, G. Ponce-Campos, V. Sclater, & Timothy Strickland. Agroecoregions resulting from novel clustering methods: Production variables. Submitted to the International Association of Landscape Ecology (LALE) - North American Annual Meeting.

Agroecoregions resulting from novel clustering methods: Human dimensions variables

Chandra Holifield Collins, Claire Baffaut, A. Bean, Patrick Clark, Alisa Coffin, Sarah Goslee. **John Hendrickson**, G. Ponce-Campos, V. Sclater, & Timothy Strickland. Agroecoregions resulting from novel clustering methods: Human dimensions variables. US-International Association for Landscape Ecology. Submitted to the International Association of Landscape Ecology (LALE) - North American Annual Meeting.

Assimilating SMAP-based soil moisture products into epic crop model for improved simulation of surface and subsurface soil moisture

Rohit Nandan, Varaprasad Bandaru, Michael Cosh, Sandeep Naga, Pradeep Wagle, **Nicanor Saliendra**, **Mark Liebig**, Curtis Jones, Rajat Bindlish, Kelly Thorp, & Chris Justice. Assimilating SMAP-based soil moisture products into epic crop model for improved simulation of surface and subsurface soil moisture. Presentation at American Geophysics Union AGU Meetings, Chicago, IL. Dec. 12-16, 2022.

Greenhouse gas flux from prairie dog mounds

Mark Liebig. Greenhouse gas flux from prairie dog mounds. Poster presentation for Society for Range Management Annual Meeting, 6-10 Feb 2022, Albuquerque, NM.

Potential benefits of tanniferous forages in integrative crop-livestock agroecosystems

Andrea Clemensen, Jonathan Halvorson, Rachel Christiansen, & **Scott Kronberg**. Potential benefits of tanniferous forages in integrative crop-livestock agroecosystems. Poster presentation for the Society for Range Management Annual Meetings, Albuquerque, NM.

Evaluation of yellow-flowered subspecies Falcata alfalfa to purple flowered Medicago sativa for Northern Plains: Productivity, nutrient profile, and in vitro true dry matter digestibility

Rachel Christiansen & John Hendrickson. Evaluation of yellow-flowered subspecies Falcata alfalfa to purple flowered Medicago sativa for Northern Plains: Productivity, nutrient profile, and in vitro true dry matter digestibility. Shared as supplement in Journal of Animal Science 100, pp. 285-286.

Cattle performance and forage nutrients while grazing an integrated crop-livestock system compared to grass pasture in the northern Great Plains

Rachel Christensen, Scott Kronberg, John Hendrickson, David Archer, & Mark Liebig. Cattle performance and forage nutrients while grazing an integrated crop-livestock system compared to grass pasture in the northern Great Plains

Crested wheatgrass dominated grassland benefits from native species restoration in the Grand River National Grassland

Rachel Christensen & John Hendrickson. Crested wheatgrass dominated grassland benefits from native species restoration in the Grand River National Grassland

Data Management – Plans, Storage, and Access (A PSA, public service announcement)

Holly Johnson, N. Kaplan, **John Hendrickson**, J.D. Derner. Data Management – Plans, Storage, and Access (A PSA, public service announcement).

Drought and fire effects on a Kentucky Bluegrass invaded Northern Great Plains grassland

Chantel Kobilansky, David Toledo, John Hendrickson, & **Andrew Carrlson**. Drought effects on plant species composition and root biomass in a Kentucky bluegrass invaded northern Great Plains rangeland

Early-season corn stand count and spatial distribution using UAV imagery using open-source images

H. Pathak, **Igathinathane Cannayen (NDSU),** P. Flores, S. Shajahan, & **David Archer**. Early-season corn stand count and spatial distribution using UAV imagery using open-source Images.

From data to Digital Object Identifier (DOI)

N.E. Kaplan, **Holly Johnson**, J.D. Derner, **John Hendrickson**. From data to Digital Object Identifier (DOI). Presented at the Society for Rane Management.

Impact of fire and drought on axillary bud numbers in Kentucky bluegrass (Poa pratensis L.)

John Hendrickson, L. Binstock, E.S. Dekeyser, **David Toledo**, B. Kobiela, **Andrea Clemensen**, **Andrew Carrlson**, **Chantel Kobilansky**. Impact of fire and drought on axillary bud numbers in Kentucky bluegrass (Poa pratensis L.)

The influence of herbivory and ecological site on the persistence of a native perennial cool-season grass. An exploration from the axillary bud to the community level

John Hendrickson, … **Mark Liebig**, **Igathinathane Cannayen**, … & J. Garrett. The influence of herbivory and ecological site on the persistence of a native perennial cool-season grass. An exploration from the axillary bud to the community level.

Wrangling long-term livestock production data in a digital online program

N. Kaplan, J.D. Derner, **Holly Johnson, John Hendrickson**, & B.W. Hess. Wrangling long-term livestock production data in a digital online program. Presented at the Plant and Animal Genome Conference

Long Term Management
2022 Updates

Soil Quality Management: The Forage Phase.

John Hendrickson, Rachael Christensen, Mark Liebig, Andrea Clemensen, David Archer, and Jonathan Halvorson

The Soil Quality Management Project (SQM) was established by Don Tanaka in 1993. The original purpose was to evaluate the impact of tillage and crop rotation on soil quality. While the focus of the project continued to be on soil quality, specific treatments were modified over time. Changes can be found in the Area 4 Research Results reports.

In 2018, a decision was made to switch from annual crops to a perennial phase because of labor constraints. However, it was also recognized that perennial crops were an important part of soil health and regenerative agriculture. The existence of SQM and the timing of the switch provided researchers with an excellent chance to evaluate how previous soil management strategies could influence yield and composition of perennial forages.

In June 2019, an intermediate wheatgrass-alfalfa mixture was seeded to the entire SQM study site. Frequency grids, a method to quickly measure forage establishment, were taken in the fall of that year and the spring of 2020. In 2020 and 2021, a forage harvester was used to estimate total productivity from each plot. In addition, small quadrates (1/8 m^2) were used to determine species composition by clipping alfalfa, intermediate wheatgrass and weeds separately. There were two harvests taken each year. One in June and the other in August.

Clipping for determining proportion of alfalfa, intermediate wheatgrass and weeds in forage.

The same approach was used in 2022. Statistical analysis indicate that harvest date and rotation resulted in differences in yield for 1) total yield (alfalfa + intermediate wheatgrass + weeds), 2) forage yield (alfalfa + intermediate wheatgrass) and 3) alfalfa yield (Table 1). However, intermediate wheatgrass yield in the continuous spring wheat with residue removed treatment (one the pre 2018 treatments) had the lowest production during the June harvest but highest production in the August harvest. Intermediate wheatgrass had the greatest production in June

(3059 vs 679 lbs. per acre for June and August, respectively) while alfalfa had greater production in August.

We have to do more digging into the statistics, but our current interpretation is that annual crop rotation rather than tillage management had the greatest impact on establishment and yield of subsequent forage crops.

Table 1. Harvest weight in pounds per acre for alfalfa, alfalfa plus intermediate wheatgrass (Forage Yield) and alfalfa, intermediate wheatgrass, and weeds (Total Yield).

Harvest	**Alfalfa**	**Forage Yield**	**Total Yield**
		Pounds per acre	
June	1350 b	4423 a	4523 a
Aug	2453 a	3119 b	3547 b
Rotation			
Continuous Spring Wheat (Residue Left in Place)	1139 c	3015 b	3132 c
Continuous Spring Wheat (Residue Removed)	1779 ab	3922 ab	4025 abc
Spring Wheat-Corn-Cover Crop	1862 b	3451 b	3695 bc
Spring Wheat-Corn-Soybean	2503 a	4606 a	4764 a
Spring Wheat-Fallow	2075 ab	3708 b	3769 bc
Spring Wheat-Soybean	2051 ab	3923 ab	4174 ab

*Different letters within each column indicate significant different at P≤ 0.05.

LTAR Northern Plains Croplands Common Experiment: 2022 Summary

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Core ideas

- 2022 was the fourth year of the LTAR Northern Plains Croplands Common Experiment, where prevailing cropping practices (Prevailing Practice; PP) are compared to alternative cropping practices (Alternative Practice; AP) at plot- and field-scale.
- Growing season precipitation in 2022 was similar to the long-term average (14.7” in 2022 vs. 14.3” long-term). Most precipitation fell in a single month (5.7” in July).
- Grain yields were near normal in 2022. At the plot-scale, no differences in grain yield were observed between treatments for spring wheat and soybean, while corn grain yield was about 25% lower under the AP treatment compared to PP.
- At the field scale, spring wheat grain yield was 4 bu/ac lower in the AP treatment compared to the PP treatment.
- Late fall cover crop biomass production in AP wheat and corn treatments were negligible, averaging 30 (wheat) and 150 (corn) lbs/ac before a killing frost.
- Overwintering cover crop species were more abundant, with aboveground biomass averaging 189 and 855 lbs/ac following wheat and corn in early spring.
- Carbon dioxide uptake from the atmosphere was greater during the growing season in the PP treatment compared to the AP treatment.

Introduction

The Long-Term Agroecosystem Research (LTAR) Croplands Common Experiment (CCE) supports long-term observational measurements throughout the U.S. Research conducted at LTAR CCE sites will generate important information on the impact of various management practices. Information gathered from the LTAR CCE project is meant to help producers make cropland management choices that offer improved economic, social, and environmental outcomes.

More information about the LTAR CCE is available at https://ltar.ars.usda.gov/.

Background

Cropland agriculture in the United States is dominated by an emphasis on provisioning services by applying energy and economic intensive inputs through uniform production systems across variable landscapes.

This approach to cropland management use is not sustainable and has contributed to many negative impacts related to yield, soil health, water quality, and air quality.

Despite this complicated context, cropland agriculture has the potential to provide many ecosystem services in addition to yield: pollinator habitats, flood protection, pest/disease suppression, soil fertility, and much more. Understanding how cropland agriculture affects the balance of ecosystem services under different forms of management over the long-term is a largely unexplored area that can have many benefits for producers, economic and otherwise.

The LTAR CCE at NGPRL is generating data for the evaluation of alternative management practices for cropland agriculture in the northern Great Plains. Specifically, the LTAR CCE is contrasting prevailing cropping practices (Prevailing practice; PP) in central North Dakota with alternative /adaptive cropping practices using no-till management,

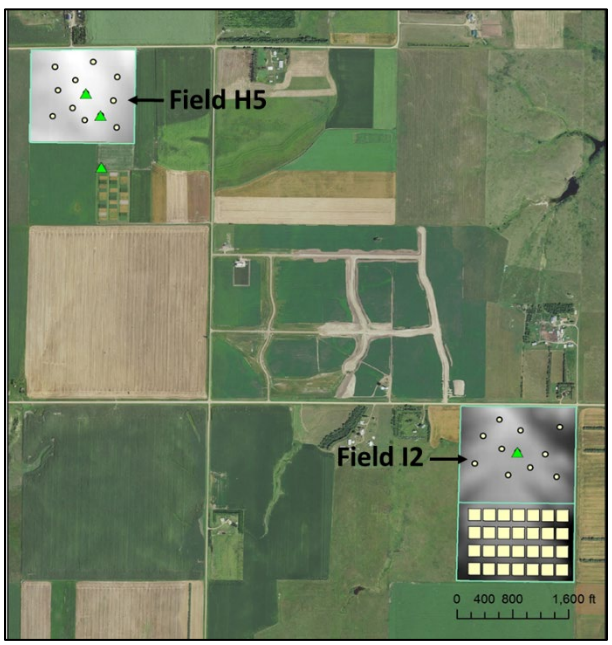


Image 1: Field site locations for LTAR-NP Croplands Common Experiment on the Area 4 SCD Cooperative Research Farm. Fields H5 and I2 represent the 'Prevailing practice' (PP) and 'Alternative practice' (AP1) treatments, respectively. The plot-scale study is located south of Field I2.

Image 2: LTAR Northern Plains Croplands Common Experiment, aerial view

integrated cropping, and cover crops (Alternative practice; AP) (Table 1).

For the initial phase of the experiment (2019-2024), a **spring wheat – corn – soybean rotation with and without cover crops** is being evaluated at two spatial scales: plot and field (Fig. 1). The experiment is conducted on the Area 4 SCD Cooperative Research Farm on Temvik-Wilton silt loam soils.

Summary of Field Activities

Spring wheat, corn, and soybean plots were sprayed with Glystar 5 Extra @ 32 oz/ac + 2,4-D Amine 4 @ 8 oz/ac + Class Act @ 1 gal/100 gal + Jackhammer @ 1 qt/100 gal on May 16th.

Spring wheat plots were seeded with a JD 750 drill on May 24th. Standing stubble in corn plots was rolled with an 8 ft roller on May 24th. Corn and soybean plots were seeded with a JD MaxEmerge XP planter on May 27th and June 3rd.

Wheat plots were sprayed with WideMatch @ 16 oz/ac + Tacoma @ 10 oz/ac on June 22nd. On June 24th AP corn plots were sprayed with Glystar 5 Extra @ 32 oz/ac + Jackhammer @ 2 qt/100 gal; PP corn plots were sprayed with the same Glystar plus DiFlexx @ 8 oz/ac. On June 28th, soybean plots were sprayed with

Basagran @ 24 oz/ac + Glystar 5 Extra @ 32 oz/ac + Savvy @ 12 oz/ac + Jackhammer @ 1 qt/100 gal.

Cover crops were interseeded into AP corn plots on July 1st with an Interseeder drill in three 7.5 in. rows per interrow. Additional field activities are outlined in Table 2.

All crops were sampled for grain yield using a Wintersteiger plot combine. Spring wheat plots were sampled August 31st. The PP treatment of wheat was cleared with a JD 9650 combine using a 35 ft straight header without a straw chopper for baling the straw September 6th. The AP wheat treatment was cleared using a stripper head with a straw chopper and these plots were seeded with a cover crop mix on September 7th (Table 2).

Soybean plots were sampled October 12th for yield and cleared with a JD 6620 combine and a 20-ft straight head. Corn plots were sampled for yield November 1st and cleared with a JD 6620 combine with a 6-row head.

Image 3: Soybean under Alternative Practice 1 (AP1) treatment (left) and Prevailing Practice (right). Both photos taken the same day, 5 August 2022

Image 4 Alternative Practice Corn with overwintered cover crops, photo taken on 5 May 2022

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

	Component	Description
Prevailing Practice ('PP')	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 ('AP1')	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. Use of stripper header for spring wheat grain harvest.

	Component	Description
Alternative Practice ('AP2')	Type	Alfalfa (*Medicago sativa* L.) + Intermediate wheatgrass
	Nutrient management	NDSU recommendation at planting
	Management	Harvest as hay (1-2 cuttings per year)

Table 2: Crop, fertilizer, and harvest information for plot-scale treatments.

Crop	Cultivar or type	Planting rate	Planting Date	Fertilizer	Harvest Date
Alternative (AP1)					
Spring wheat	ND VitPro	90 lb/ac	5/24/22	Urea - 50 lb N/ac MAP - 133 lb mat./ac	Hand 8/19/22 Combine 8/31/22 Cleared 9/06/22
Cover crop mix:			9/7/22		
• Pea	Vine	12.9 lb/ac			
• Wheat	Winter	12.9 lb/ac			
• Radish	Oilseed	0.4 lb/ac			
Corn	Croplan CP2288VT2	24,500 seeds/ac	5/27/22	Urea - 50 lb N/ac MAP - 133 lb mat./ac	Hand 10/21/22 Combine 11/01/22
Cover crop mix:		42.0 lb/ac	7/01/22	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	Croplan CP0426X	170,000 seeds/ac	6/03/22	MAP – 66 lb mat./ac	Hand 10/7/22 Combine 10/12/22
Prevailing practice (PP)					
Spring wheat	ND VitPro	90 lb/ac	5/24/22	Urea - 80 lb N/ac MAP - 133 lb mat./ac	Hand 8/19/22 Combine 8/31/22 Baling 9/09/22
Corn	Croplan CP2288VT2	24,500 seeds/ac	5/27/22	Urea - 120 lb N/ac MAP - 133 lb mat./ac	Hand 10/21/22 Combine 11/01/22
Soybean	Croplan CP0426X	170,000 seeds/ac	6/03/22	MAP – 66 lb mat./ac	Hand 10/7/22 Combine 10/12/22
Alternative (AP2)			6/11/19 (4th year)	MAP - 133 lb mat./ac	Hand (3): 6/27/22, 8/12/22, 10/5/22 Swath (2): 6/29/22, 8/11/22
Intermediate wheat grass + Alfalfa	Manska Vernal	5 lb/ac 5 lb/ac			

Plot-Scale Summary

Spring wheat and soybean grain yield did not differ between PP and AP1 treatments in 2022 (Table 3). Corn grain yield, however, was about 25% greater under PP compared to AP1 due to cover crops competition for water and nutrients in the latter. Stover production was similar between treatments for all crops.

Total aboveground biomass and harvest index for corn were greater under PP compared to AP1 (Fig. 2). Cover crop biomass prior to a killing frost was negligible following spring wheat (30 lbs/ac). Cover crop biomass interseeded into corn was also limited, averaging 150 lb/ac just before a killing frost. Cover crop biomass was greatest from overwintering species in early spring, with 189 lb/ac prior to corn and 855 lb/ac prior to soybean (Table 3).

Cover crop species present in spring were dominated by cool-season grasses (i.e., winter rye, winter wheat, and spring triticale). The perennial alternative treatment (AP2) of alfalfa + intermediate wheatgrass was cut and baled twice over the growing season, generating aboveground biomass of 3.5 ton/ac.

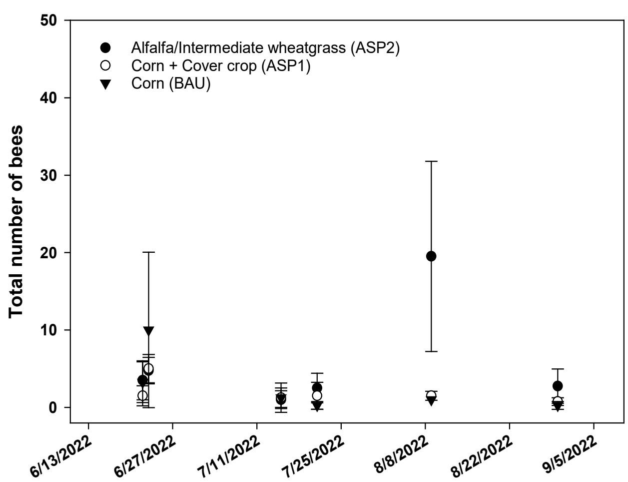


Figure 2 Total number of bees (± standard deviation) across six sampling dates in plot-scale treatments. Treatments were alfalfa/intermediate wheatgrass (AP2), corn with interseeded cover crops (AP1), and corn (PP).

Preplant soil moisture was abundant across the soil profile in 2022 and only differed between treatments in corn, where the AP1 treatment was greater than PP at the 2-3 ft depth (Fig. 3c).

Postharvest soil moisture was lower in AP1 than PP following spring wheat (Fig. 3b).

Soil water status decreased under all crops between preplant and postharvest samplings, ranging from -4.5 to -6.7 inches per 5 ft depth. Soil water depletion did not differ between treatments for any crop.

Insect evaluations were conducted over the 2022 growing season within three plot-scale treatments of the LTAR CCE. Treatments included alfalfa/intermediate wheatgrass (AP2), corn with interseeded cover crops (AP1), and corn (PP).

Flowers in alfalfa (AP2) and interseeded cowpea (AP1) were hypothesized increase insect presence. The evaluations involved deploying bowls of dilute soapy water in plots over the course of a day and inventorying insects landing in each bowl.

Differences in total bees among treatments were limited to the August 9th sampling date, where alfalfa/intermediate wheatgrass hosted more bees than either corn treatment (Fig. 4). At no time over the evaluation period were bees more abundant in corn with interseeded cover crops than corn without cover crops. Future insect evaluations will be conducted at the field scale.

Table 3: Grain yield, stover, aboveground biomass, and harvest index (± standard error).

Treatment − Crop Phase	Grain Yield	Stover	Aboveground biomass	Harvest index
	bu/ac	------- ton/ac -----------		
PP − Spring wheat	50 ± 2	2.4 ± 0.1	3.9 ± 0.2	0.39
AP1 − Spring wheat	48 ± 1	2.2 ± 0.1	3.7 ± 0.1	0.40
AP1 − Cover crop (late fall)			30 ± 3†	
PP − Corn	129 ± 5	2.4 ± 0.1	6.1 ± 0.3	0.60
AP1 − Corn	99 ± 5	2.2 ± 0.1	4.9 ± 0.2	0.56
AP1 − Cover crop (preplant)			189 ± 61	
AP1 − Cover crop (late fall)			150 ± 17	
PP − Soybean	38 ± 2	1.1 ± 0.1	2.2 ± 0.1	0.51
AP1 − Soybean	42 ± 2	1.2 ± 0.1	2.4 ± 0.1	0.51
AP1 − Cover crop (preplant)			855 ± 118	
AP2 − Alfalfa/Intermediate wheatgrass			3.5 ± 0.2	

†Cover crop biomass was measured prior to a killing frost (spring wheat, corn) or prior to planting (soybean) and is expressed as lbs/ac.

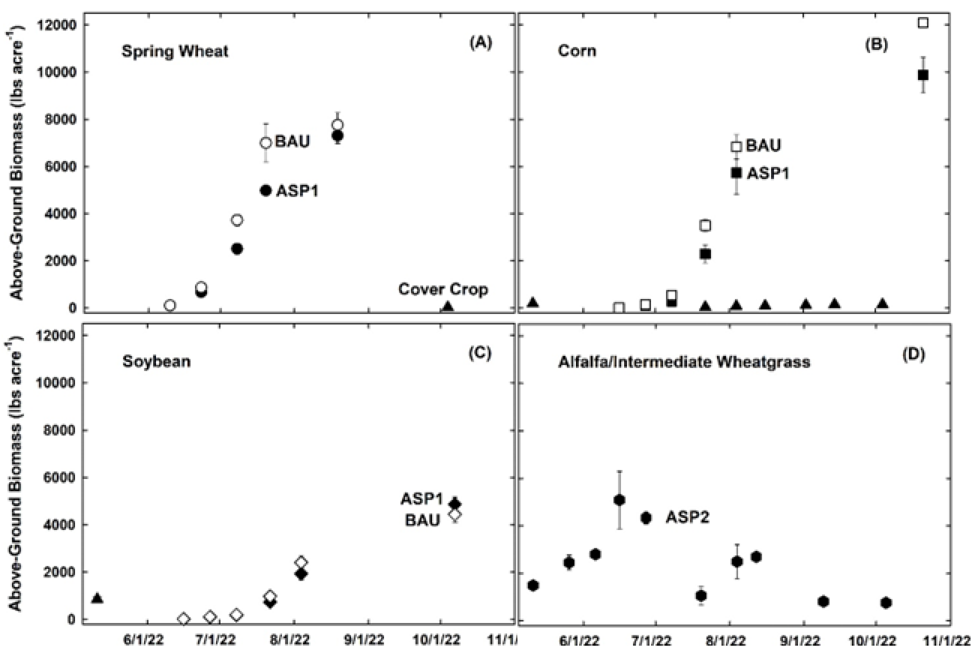


Figure 2: Growing season above-ground biomass (AGB, lbs acre-1) for the Alternative (AP1 and AP2, filled symbols) and Prevailing practice (PP, open symbols) treatments:
(A) spring wheat phase (circles) and cover crop (triangle) in AP1-SW
(B) corn phase (squares) and cover crop (triangles) in AP1-C
(C) soybean phase (diamonds) and cover crop (triangle), and
(D) perennial system (hexagons, AP2-AF-IW, alfalfa/intermediate wheatgrass).

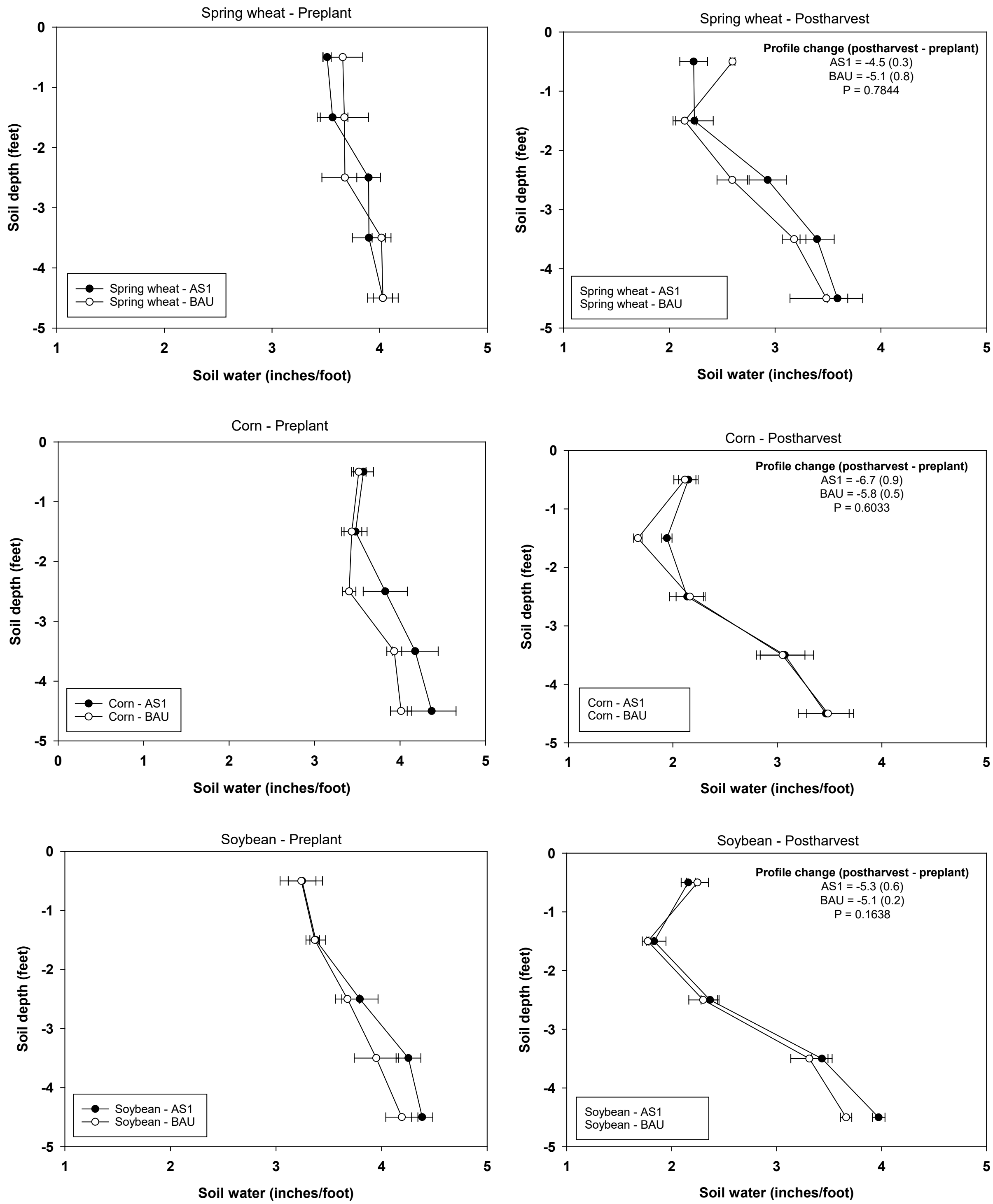


Figure 3: Profile soil water status before planting and after harvest for the Alternative (AP1) and Prevailing practice (PP) treatments: spring wheat (A, B), corn (C, D), and soybean (E, F).

Field-Scale Summary

Growing conditions at fields H5 (Prevailing Practice, PP) and I2 (Alternative Practice, AP) in 2022 were similar (Tables 4 & 5; Fig. 5). Annual precipitation received at both fields was similar to the long-term average, though most precipitation was received in a single month (July). Volumetric soil water content at the 2” depth was about 2% greater in AP treatment compared to the PP treatment.

Spring wheat grain yield was about 4 bu/ac greater in the PP treatment compared to the AP treatment (41.7 vs. 37.3 bu/ac, respectively). Fifty-five straw bales were removed from the PP treatment prior to the November blizzard, with an average bale weight of 953 lbs.

Treatments had similar impacts on annual CO_2 flux in 2022, with net ecosystem exchange (NEE) negative for the PP treatment (C uptake of 208 lbs CO_2-C/ac/yr) and AP treatment (C uptake of 138 lbs CO_2-C/ac/yr) (Table 6). However, high variability in CO_2 fluxes over the course of the year resulted in both annual NEE values not being different from zero.

Over the course of the growing season, CO_2 uptake was over 800 lbs CO_2-C/ac greater in the PP treatment compared to the AP treatment (Table 7), aligning with greater grain yield observed in the former. Evapotranspiration in 2022 was greater under the AP treatment compared to the PP treatment, a difference driven mostly by greater water vapor loss from the AP treatment during the dormant season (Table 7; Fig. 6).

Image 5: Spring wheat in the Alternative Practice Field I2. 05 August 2022

Appendix

Table 4 Annual averages (± standard error) of incoming or global solar radiation (R_g), vapor pressure deficit (VPD), relative humidity (RH), air (T_{air}) and soil (T_{soil}) temperature, soil water content (SWC), and total precipitation (PCPN). Within a column or variable, means followed by different letter(s) are significantly different (P = 0.05).

Treatment (Field)	n Days	R_g MJ m^{-2} d^{-1}	VPD hPa	RH %	T_{air} °C	T_{soil} °C	SWC %, v/v	PCPN in yr^{-1}
PP (H5)	365	14.4 ± 0.4	4.76 ± 0.24	70.4 ± 0.7	4.9 ± 0.7	8.3 ± 0.5	18.9 ± 0.4 b	17.3
AP (I2)	365	14.7 ± 0.4	4.84 ± 0.24	70.2 ± 0.7	5.1 ± 0.7	8.2 ± 0.5	21.1 ± 0.5 a	18.0

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). Within a column or variable, means followed by different letter(s) are significantly different (P = 0.05).

Season (Period)	Field	n Days	R_g MJ m^{-2} d^{-1}	VPD hPa	RH %	T_{air} °C	T_{soil} °C	SWC %, v/v	PCPN in $season^{-1}$
Growing (5/21-8/20)	PP (H5)	92	22.7 ± 0.6	8.4 ± 0.4	68.8 ± 1.4 ab	19.4 ± 0.4	20.2 ± 0.4	22.0 ± 0.8 b	9.3
	AP (I2)	92	22.9 ± 0.6	8.7 ± 0.4	67.7 ± 1.4 b	19.6 ± 0.4	20.0 ± 0.4	25.3 ± 0.8 a	9.4
Dormant (8/21-5/20)	PP (H5)	273	11.5 ± 0.4	3.5 ± 0.2	70.9 ± 0.8 ab	0.1 ± 0.7	4.3 ± 0.5	17.9 ± 0.4 d	8.0
	AP (I2)	273	11.9 ± 0.4	3.5 ± 0.2	71.0 ± 0.8 a	0.2 ± 0.7	4.2 ± 0.5	19.7 ± 0.5 c	8.6

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. Data are preliminary and may undergo minor edits following additional processing.

Field	n Days	NEE	ER	GEP	ET	H	NEE	ER	GEP	ET	H
		----------- 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}
PP (H5)	365	-0.57 ± 1.25	19.7 ± 1.1	20.2 ± 2.2	0.054 ± 0.004	1.41 ± 0.12	-208 ± 456	7177 ± 394	7385 ± 809	19.8 ± 1.3	515 ± 44
AP (I2)	365	-0.38 ± 1.04	15.7 ± 1.0	16.1 ± 2.0	0.053 ± 0.003	1.57 ± 0.12	-138 ± 380	5734 ± 350	5872 ± 693	19.4 ± 1.2	572 ± 48

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. Data are preliminary and may undergo minor edits following additional processing.

Season (Period)	Field	n Days	NEE	ER	GEP	ET	H	NEE	ER	GEP	ET	H
			---------- 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 (5/21-8/20)	PP (H5)	92	-31.2 ± 3.2	49.1 ± 2.2	80.3 ± 5.0	0.148 ± 0.008	1.66 ± 0.24	-2869	4516	7385	13.6	153
	AP (I2)	92	-22.7 ± 3.0	41.1 ± 2.1	63.8 ± 4.9	0.130 ± 0.007	1.71 ± 0.27	-2090	3782	5872	12.0	157
Dormant (8/21-5/20)	PP (H5)	273	9.7 ± 0.3	9.7 ± 0.3		0.023 ± 0.001	1.33 ± 0.14	266	2661		6.2	362
	AP (I2)	273	7.2 ± 0.2	7.2 ± 0.2		0.027 ± 0.001	1.52 ± 0.15	195	1952		7.4	414

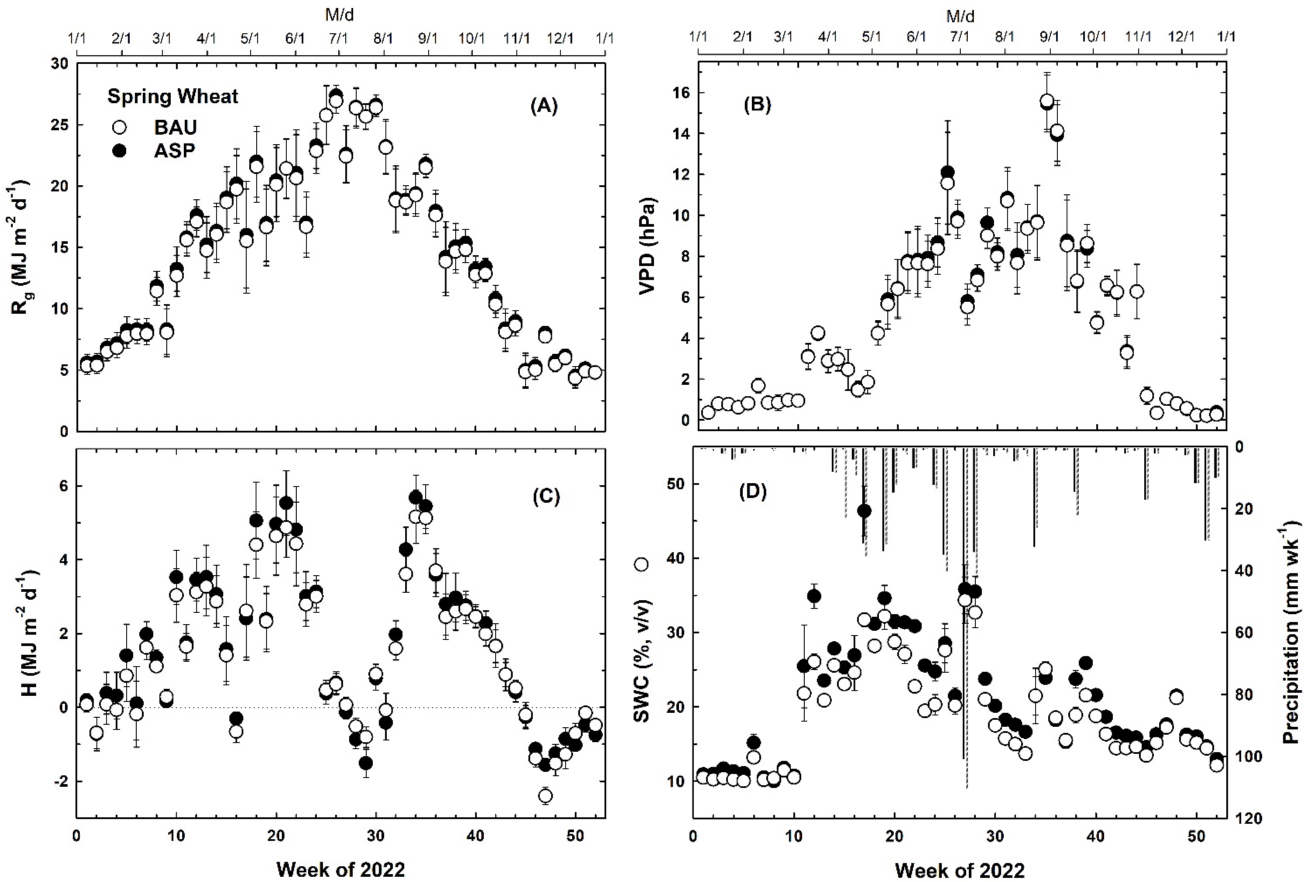


Figure 5. Weekly averages (± standard error) of (A) global or incoming solar radiation (R_g), (B) vapor pressure deficit (VPD), (C) sensible heat flux (H), and (D) soil water content at 2" depth (SWC, left Y-axis) and precipitation (right Y-axis, solid bars = PP, dashed bars = AP). Each data point is the mean (n = 7 days) from two fields (>20 ha) with contrasting cropping systems, Prevailing Practice (PP, open circles) and Alternative Practice (AP, filled circles). Data are preliminary and may undergo minor edits following additional processing

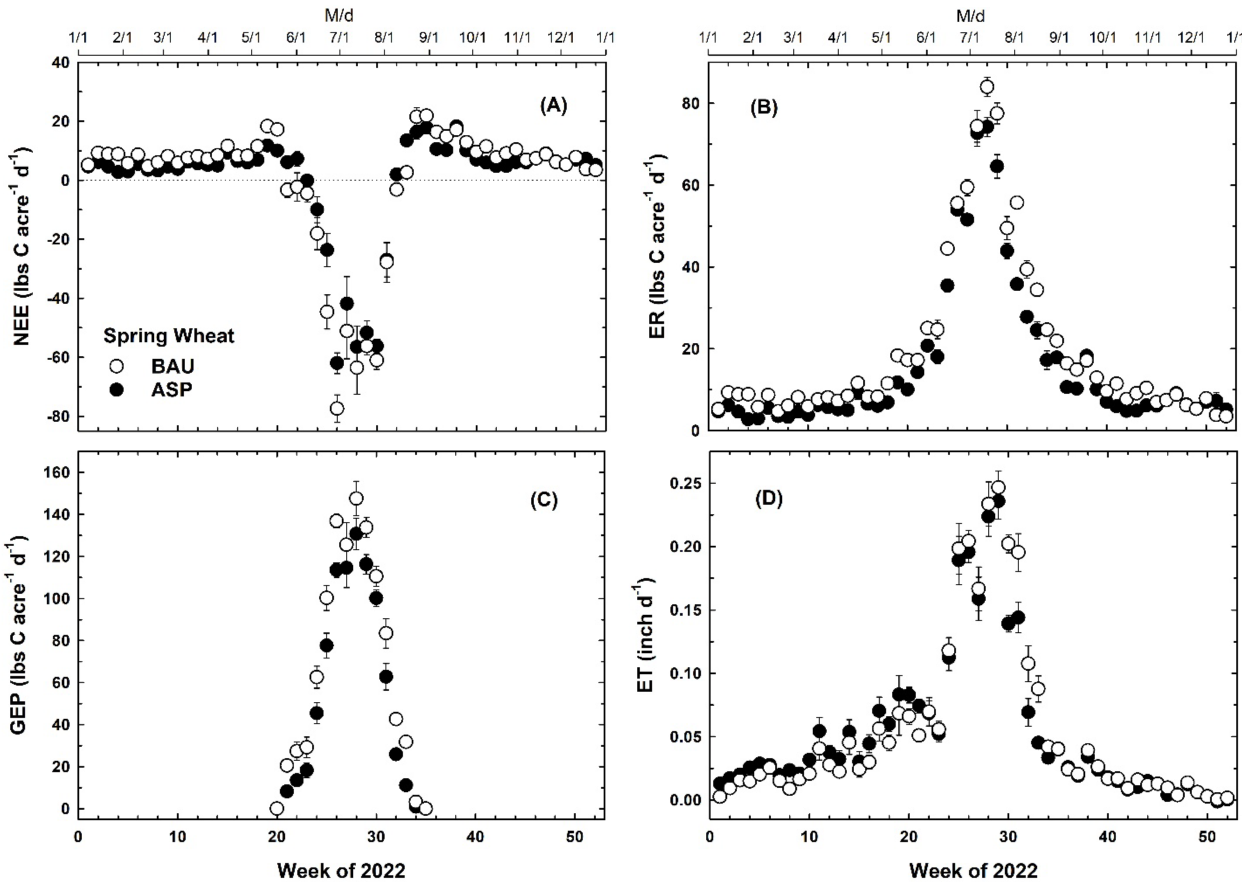


Figure 6. Weekly averages (± standard error) of (A) net ecosystem exchange for CO_2 (NEE), (B) ecosystem respiration (ER), (C) gross ecosystem production (GEP), and (D) evapotranspiration (ET) as obtained from daily summaries of eddy covariance measurements in the fourth year (spring wheat) of a 3-year crop rotation in the LTAR-NP Cropland Common Experiment in 2022. Each data point is the mean (n = 7 days) from two fields (>20 ha) with contrasting cropping systems, Prevailing practice (PP, open circles) and Alternative (AP, filled circles). Data are preliminary and may undergo minor edits following additional processing.

Integrated Crop / Livestock Systems - 2022 Summary

The Integrated Crop/Livestock (ICL) systems project was initiated in 1999 focusing on providing forages at times when native range may not be of adequate quality to maintain the rate of animal weight gain or animal maintenance.

After the 2020 crop season, the decision was made to take a 3-year pause in the project to address some weed management issues. This pause allowed us to focus on questions that were raised by our involvement with the Healthy Soil-Healthy Food-Healthy People Initiative. Specifically, we wanted to investigate the interaction between genetics, the environment and management (GxExM).

Phase 3 management (2015-2020)

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.

In 2021, the wheat-soybean-corn rotation that had previously been used on the grain-only check strips was extended to the integrated treatment areas. Grazing was discontinued, and no intercropping or cover crops were used. The grain-only check strips had not been grazed since 2014.

This lack of grazing allowed us to compare previous grazing and cover crop influence on crop production. This also provided an excellent opportunity to address grazing and cover crop management influence on a GxExM interaction focusing on the wheat phase of the crop rotation (see **GxExM microplot study** below).

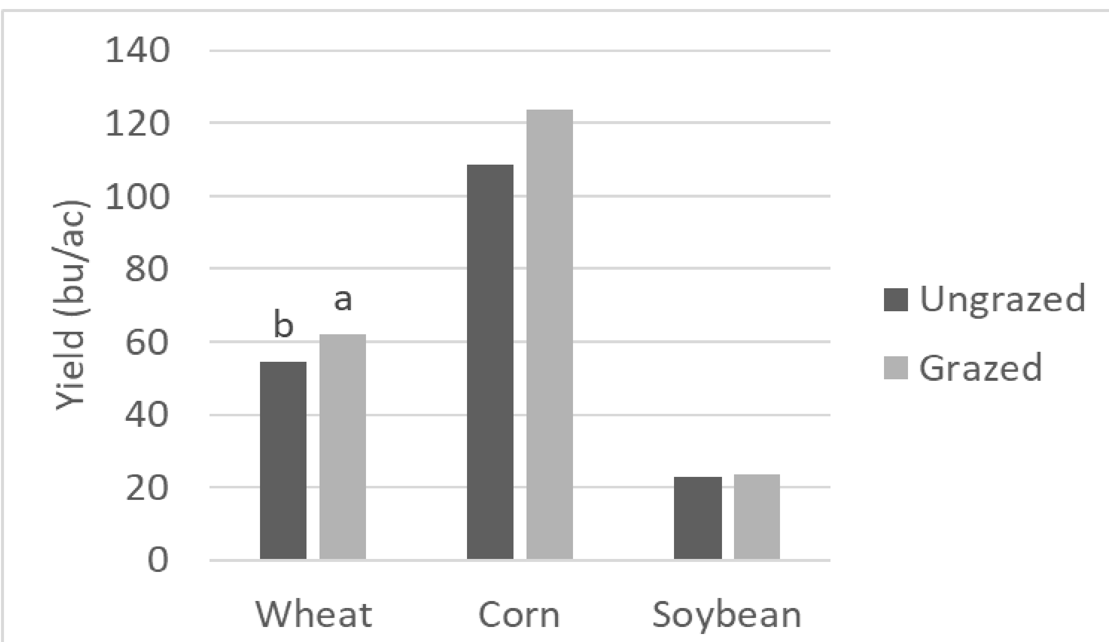
Main plot management

Spraying

- Preplant burndown was completed on 5/16/22 & all plots were sprayed with Glystar @ 32 oz/ac + Sharpen @ 1.5 oz/ac + Class Act @ 1 gal/100 gal. + Jackhammer @ 1 qt/100 gal.
- Corn plots were sprayed on 6/24/22 with Gly Star 5 Extra @ 32 oz/ac + DiFlexx @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.
- Corn plots were sprayed on 7/15/22 with Cornerstone 5 Plus @ 28 oz/ac + Class Act @ 1 gal/100 gal + Preference @ 1 qt/100 gal.
- Soybean plots were sprayed on 7/1/22 with Basagran @ 24oz/ac + Gly Star 5 Extra at 32 oz/ac + Savvy @ 12 oz/ac + Jackhammer @ 1 qt/100 gal.
- Soybean plots were sprayed on 7/29/22 with Cornerstone 5 Plus @ 32 oz/ac + Basagran @ 35 oz/ac + Jackhammer @ 1 qt/100 gal.
- Soybean plots were sprayed on 8/18/22 with Sultrus @ 2 oz/ac + Destiny @ 1 qt/100 gal.

Planting/Fertilizer

- ND VitPro spring wheat plots were planted at 90 lb/ac & fertilized with urea @ 34 lb N/ac on 6/1/22.
  - Spring wheat plots were hand sampled on 9/1/22 and combined on 9/2/22.
- Croplan CP2288VT2 corn plots were planted at 24,500 seeds/ac and fertilized with urea @ 40 lb N/ac + MAP @ 30 lb mat./ac on 6/2/22.
  - Corn plots were hand sampled on 10/18/22 and combined on 10/31/22.
- Croplan CP0426X soybean plots were planted at 170,000 seeds/ac on 6/3/22.
  - Soybean plots were hand sampled on 10/5/22 and combined on 10/11/22.



Main plot summary:

- Spring wheat yield was significantly higher in the plots that had historically been grazed and cover cropped compared to the plots that had not been grain-only since 2014.
- Although corn yield appeared to be higher in the grazed compared to the ungrazed treatment, the difference was not statistically significant.
- There were no differences in soybean yield between the grazed and ungrazed treatments.

Microplot short term study

In addition to grazing, the impact of fertilization and wheat genetics were also explored. In 2021, four different wheat varieties (Bolles, Glenn, Vitpro and Lang) were grown in plots that were previously grazed or ungrazed. The plots were further split to allow for the addition of fertilizer or left unfertilized. Because of the project setup, researchers were able to evaluate how 1) grazing or not grazing, 2) fertilizing or not fertilizing, and 3) different wheat varieties would affect wheat yield, wheat protein and wheat physiological characteristics. In addition, researchers could see if these different factors interacted with each other to influence results.

In 2022, wheat yields had a grazing by fertilizing interaction (Figure 1). The Grazed + Unfertilized treatment had greater yield than did the Ungrazed + Fertilized or the Ungrazed + Unfertilized. One factor to consider is that the Grazed + Unfertilized had cover crops periodically prior to this study and that may have provided additional nutrition to the wheat crop.

Wheat protein concentration differed between varieties, grazing and fertilizing (Table 1) as measured by our Nova analyzer (FOSS Infratec). Both grazing and fertilizing increased wheat protein but there were surprising differences between varieties. Bolles had higher protein than any of the other three varieties. The importance of the changes in protein level are linked to the marketing strategy of the producer. The Minneapolis Grain Exchange has a cutoff of 13.5% protein, but local elevators may differ.

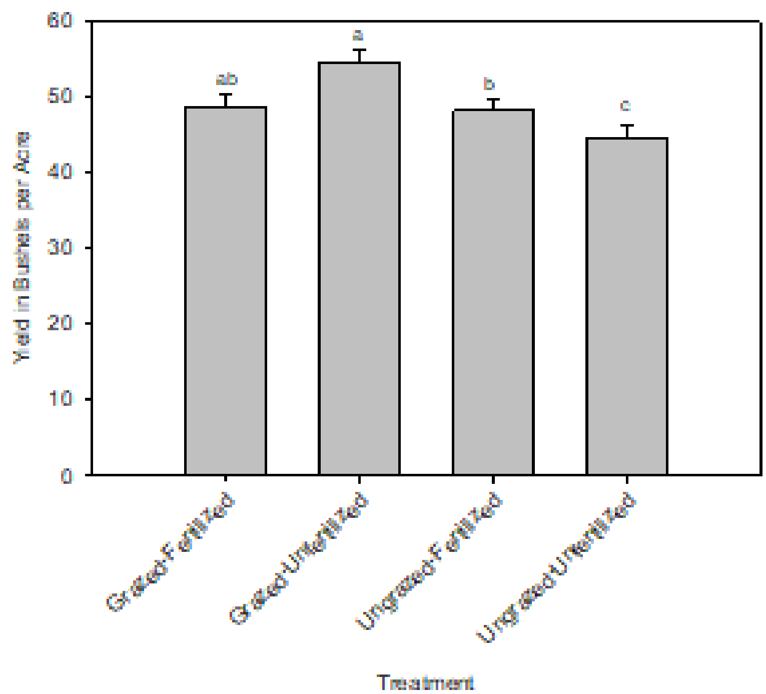


Figure 1. Wheat yield for different combinations of previous grazing history (Grazed, Ungrazed) and whether fertilizing occurred or not (Fertilized, Unfertilized).

Table 1. The influence of variety, grazing, and fertilizer management on wheat grown on the Integrated Crop-Livestock Study at Mandan, North Dakota.

Variety	**Wheat Protein %**
Bolles	14.0 (0.24)
Glenn	13.4 (0.17)
Lang	12.9 (0.24)
Vitpro	13.3 (0.16)
Grazing	
Grazed	13.8 (0.13)
Ungrazed	13.0 (0.16)
Fertilizing	
Fertilized	13.7 (0.15)
Unfertilized	13.1 (0.16)

NDVI was measured with a Trimble Greenseeker at head emergence. NDVI measurements provide an assessment of plant vigor and nutrient status. The grazing or fertilizing treatments increased NDVI relative to the Ungrazed + Unfertilized treatments (Figure 2). This indicates that grazing improved plant vigor to levels comparable with fertilizer application. Differences in NDVI due to variety were not found.

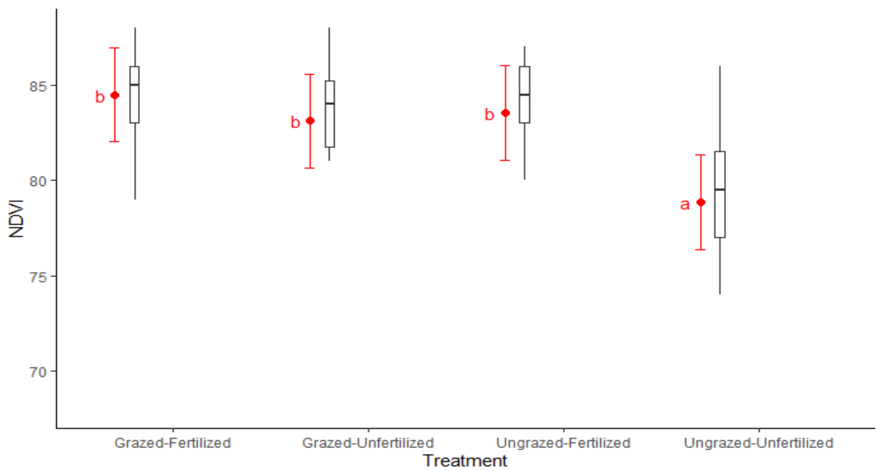


Figure 2. NDVI for different combinations of previous grazing history (Grazed, Ungrazed) and whether fertilizing occurred or not (Fertilized, Unfertilized). Red dots represent the estimated marginal means. Red whiskers represent the 95% confidence of the estimated means. Distributions are represented by the boxplots. If two or more means share the same letters, then they cannot be considered different (alpha = 0.05).

Chlorophyll content is a leaf-level measurement of nutrient status. The Ungrazed + Fertilized treatment increased chlorophyll content compared to the Ungrazed-Unfertilized control.

However, Grazed+ Fertilized and Grazed-Unfertilized treatments were indistinguishable from the other treatments (Figure 3). There were differences in chlorophyll content between varieties. Lang had the lowest chlorophyll content and Vitpro had the highest chlorophyll content (Figure 3, next page).

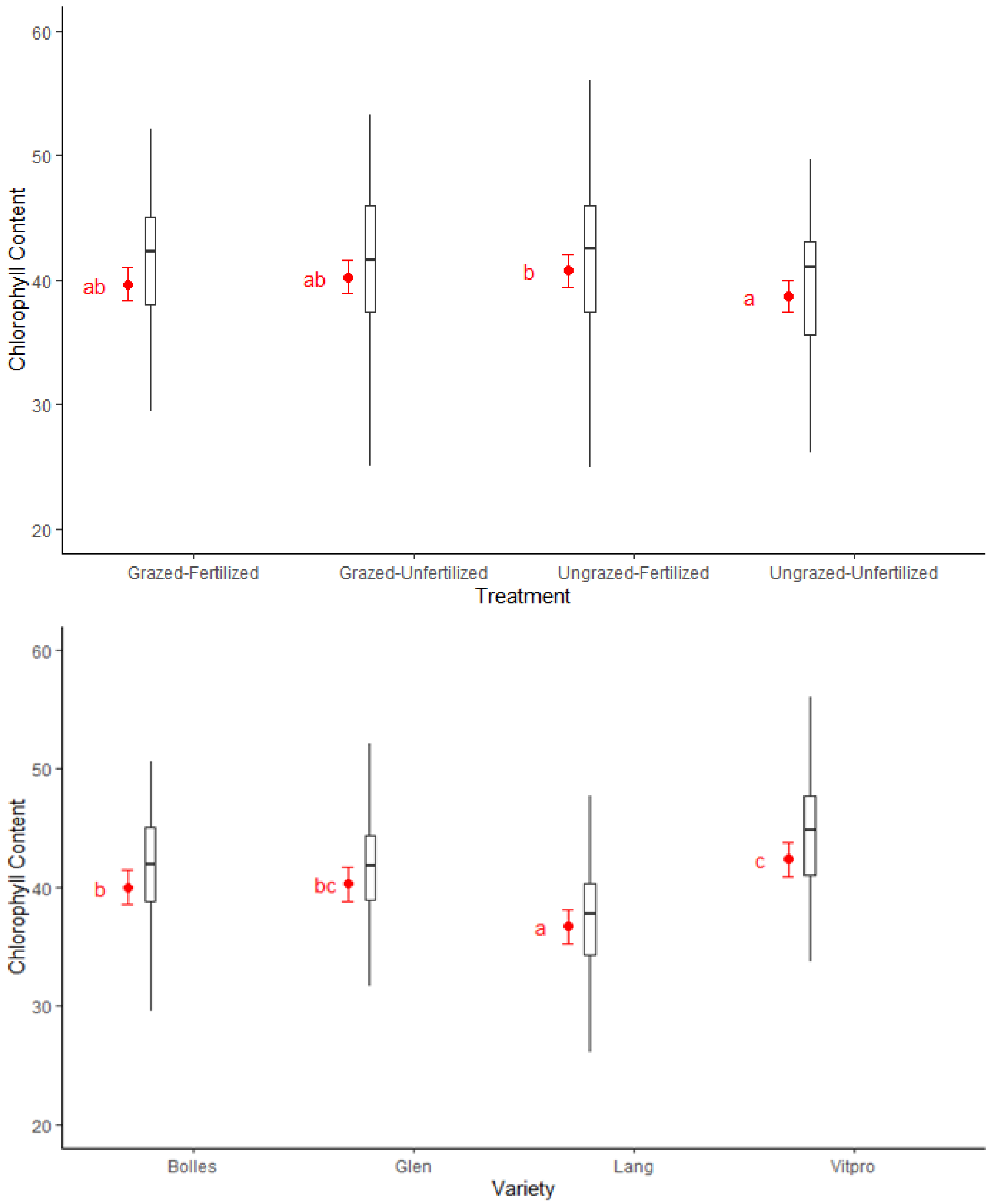


Figure 3. Chlorophyll content for different combinations of previous grazing history (Grazed, Ungrazed) whether fertilizing occurred or not (Fertilized, Unfertilized), and variety differences. Red dots represent the estimated marginal means. Red whiskers represent the 95% confidence of the estimated means. Distributions are represented by the boxplots. If two or more means share the same letters, then they cannot be considered different (alpha = 0.05).

The growing season of 2021 continued the drought that initiated in 2020. However, in 2022, precipitation from April through July was greater than the long-term (1913-2022) average. April 2022 had 1.8 times normal precipitation and July 2022 had twice as much precipitation as the long-term average.

This project will be continued at least one more year, and the effect of time after grazing and time after rotation following cover crop will continue to be studied. The results obtained show potential for management that includes grazing and cover crops to be as influential as fertilizer application on wheat, even after two years following livestock removal. Adding additional years will provide more insight on how long the effect of grazing and cover crop can influence growth and yield.

Bioenergy Cropping Systems Study Update 2022 Summary

Scientists: David Archer, Scott Kronberg, Mark Liebig, Andrea Clemensen, Craig Whippo
Support staff: Robert Kolberg and Raina Hanley

Bioenergy Cropping Systems (BCS) Study Background

Crop production can meet multiple needs including food, livestock feed, and bioenergy or biofuels. Cropping systems can be developed to focus on any one of these needs, or the systems can be developed to meet multiple needs. In any case, these systems must also protect the soil resource which drives current and future productivity.

So, how to best allocate crop production among food, feed, fuel, and soil uses? A NGPRL study was initiated in 2009 to help answer this question. The Bioenergy Cropping Systems study (BCS) looks at options for intensifying crop production (growing more grain and biomass) combined with options for intensifying crop utilization (using more of the grain and biomass for food, feed, fuel).

Crop production options have included moving from a low-intensity wheat-dry pea rotation to a higher intensity wheat-pea-corn rotation or a wheat-pea/cover crop rotation. Crop use options included moving from a low-intensity grain harvest only to higher intensity options of harvesting wheat straw, harvesting crop residues, and grazing crop residues. Some motivations for this design were to include cover crops to maintain soil cover and soil organic carbon, to include legumes to reduce needs for applying fertilizer nitrogen, and to include grazing as an alternative way to generate production from biomass to maintain soil organic carbon.

In 2021, the BCS study was modified to add another potential biofuel crop, canola, that can provide oil for edible / biofuel use that can be used as livestock feed. To accommodate this additional crop, the rotation treatments were reduced to a four-year rotation of spring wheat, dry pea, corn, and canola, and a three-year rotation of: spring wheat, dry pea intercropped with canola, and corn. The pea/canola intercrop has been included in the study to see if this may reduce the need for adding fertilizer and if intercropping results in higher productivity levels than growing the crops individually. With the addition of canola in 2021, the “harvest all crop residue” treatment was changed to only include harvesting the spring wheat straw and corn stover.

2022 BCS summary

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

1. Spring Wheat – Dry Pea – Corn – Canola (W-P-C-Can)
2. Spring Wheat – Dry Pea/Canola – Corn (W-P/Can-C)

Residue Removal:

A. No residue removed
B. Wheat straw baled and removed
C. Wheat straw and corn stover baled and removed
D. Wheat straw, corn stover, and pea residue grazed

2022 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-Can	05/23/2022	ND Vitpro	90 lb/ac	28 lb/ac urea 56 lb/ac 11-52-0	JD 750	08/30/2022
Spring Wheat W-P/Can-C	05/23/2022	ND Vitpro	90 lb/ac	0 lb/ac urea 56 lb/ac 11-52-0	JD 750	08/30/2022
Pea/Canola W-P/Can-C	05/18/2022	Durwood/ Clearfield	120 lb/ac 5 lb/ac	0 lb/ac urea 56 lb/ac 11-52-0 86 lb/ac AMS	JD 750	08/22/2022
Dry Pea W-P-C-Can	5/18/2022	Durwood	180 lb/ac	0 lb/ac urea 56 lb/ac 11-52-0	JD 750	08/22/2022
Corn W-P-C-Can	05/27/2022	Proseed 1979RR	24,500 seeds/ac	150 lb/ac urea 56 lb/ac 11-52-0	JD Max Emerge II	11/04/2022
Corn W-P/Can-C	05/27/2022	Proseed 1979RR	24,500 seeds/ac	120 lb/ac urea 56 lb/ac 11-52-0	JD Max Emerge II	11/04/2022
Canola W-P-C-Can	05/18/2022	Brevant Clearfield	5 lb/ac	0 lb/ac urea 56 lb/ac 11-52-0 86 lb/ac AMS	JD 750	08/21/2022

Fertilizer rates based on 2021 soil tests and NDSU fertilizer recommendations.

Summary:

- Due to extreme grasshopper damage canola yield was zero both as standalone crop and when interseeded with pea.
- No significant differences in spring wheat yield were observed among any treatments (Figure 1).
- Dry pea yield was significantly higher in the W-P/Can-C than in the W-P-C-Can rotation (Figure 2). This was surprising since the peas were interseeded with canola in this rotation and that dry pea yield was higher for the interseeding than when peas were planted alone.
- Corn yield was significantly higher ($\alpha = 0.10$) with no residue harvest (A) compared to where residue from all crop had been harvested (C) or grazed (D). There were no significant corn yield differences among the rotations (Figure 3).

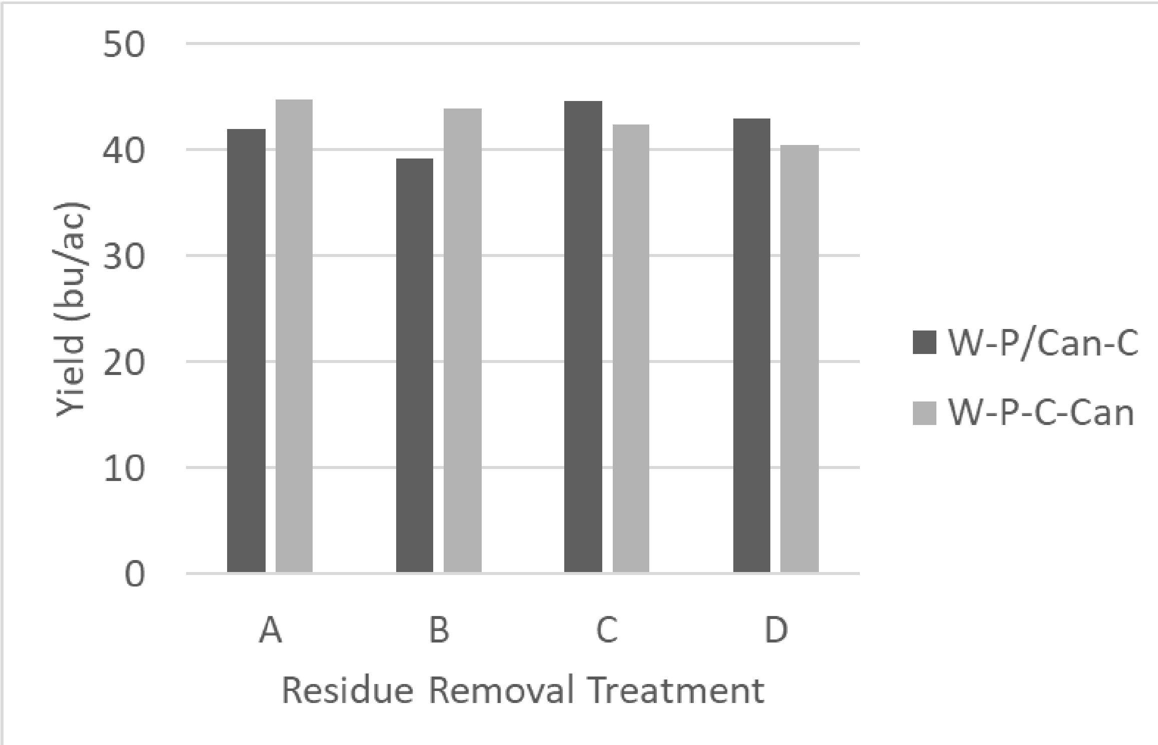


Figure 1. 2022 spring wheat seed yield as influenced by crop rotation and residue removal treatments.

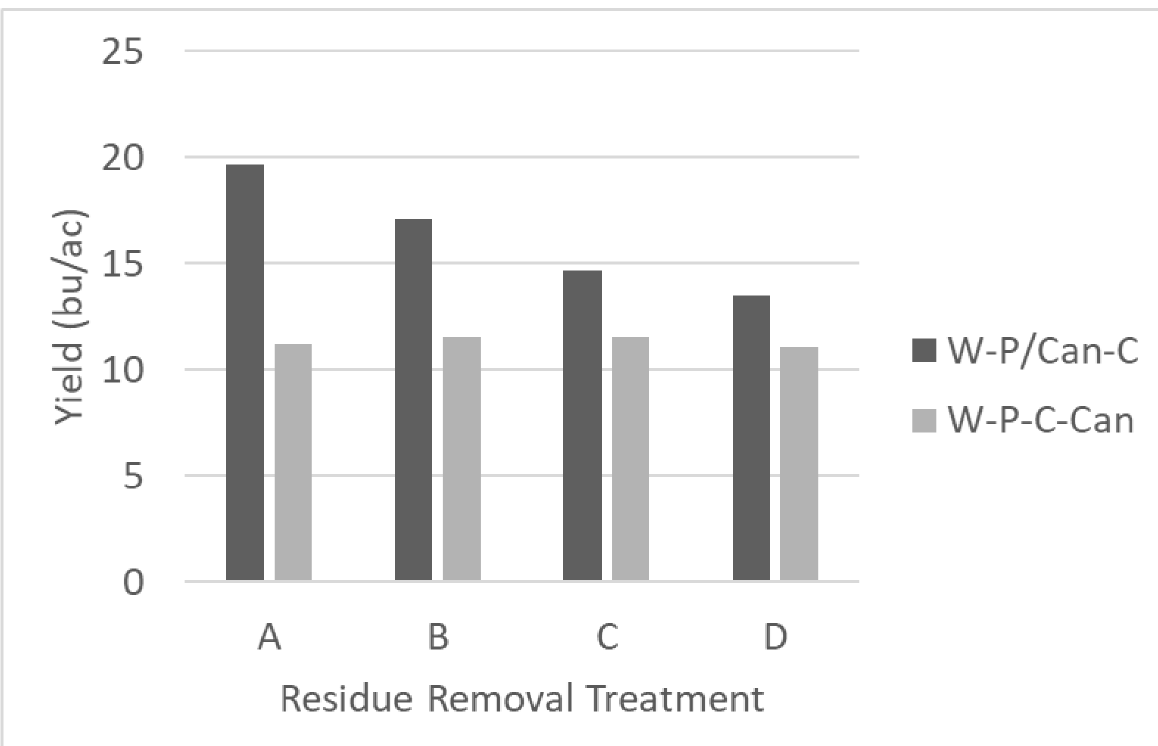


Figure 2. 2022 dry pea seed yield as influenced by crop rotation and residue removal treatments.

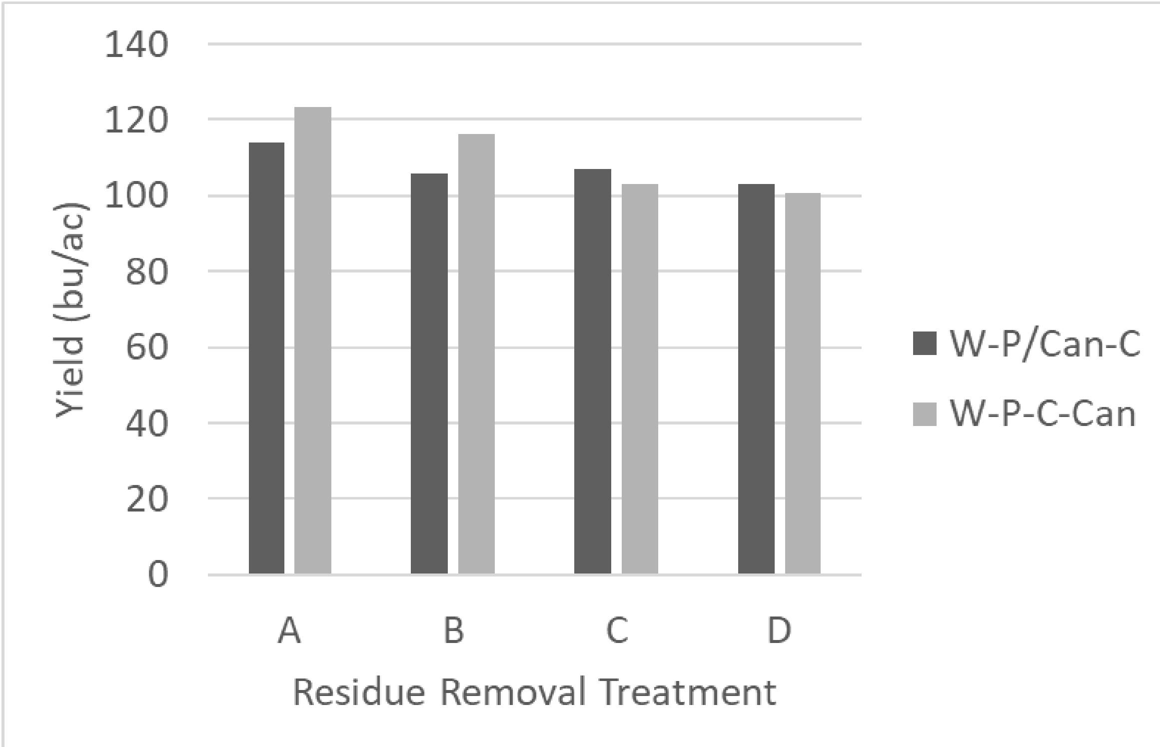
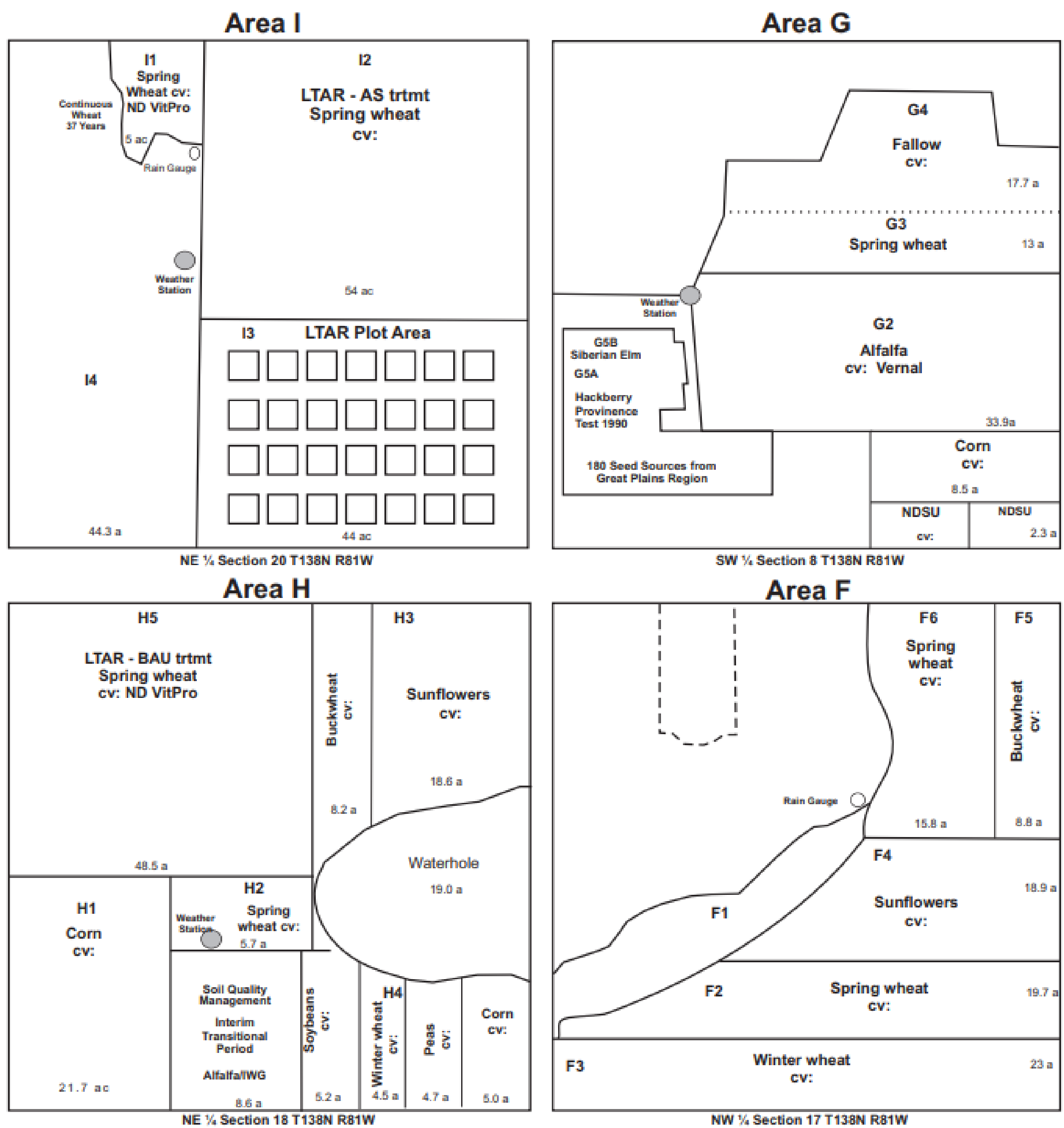


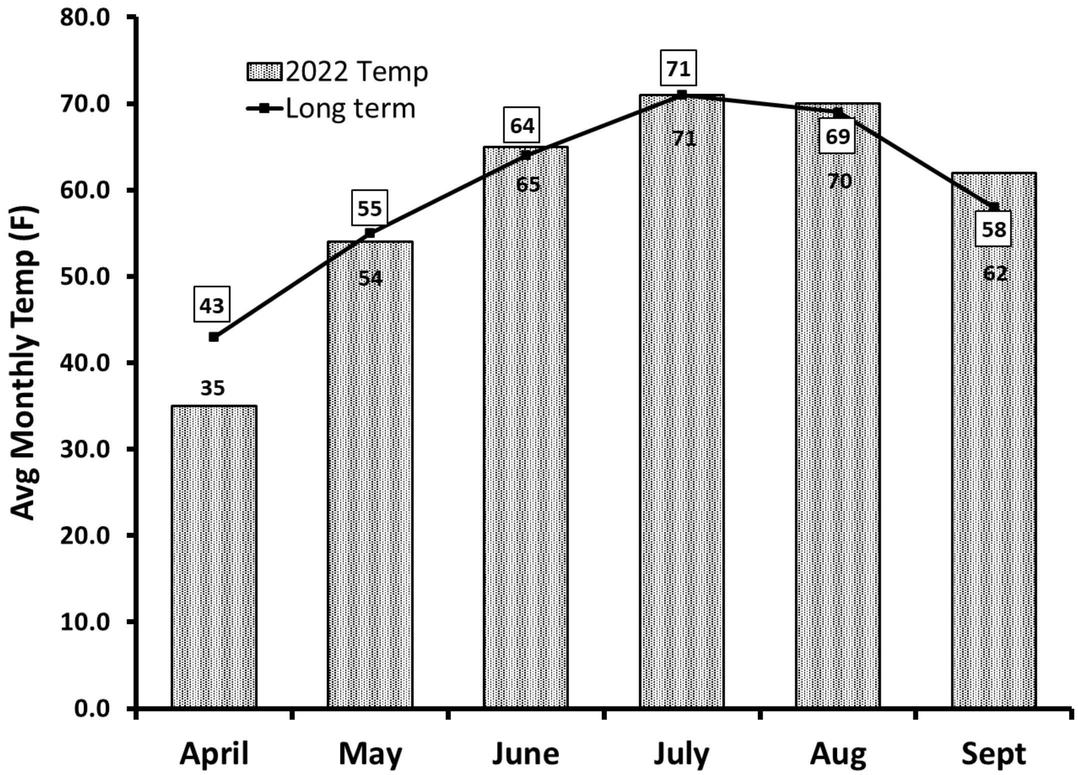
Figure 3. 2022 corn seed yield as influenced by crop rotation and residue removal treatments.

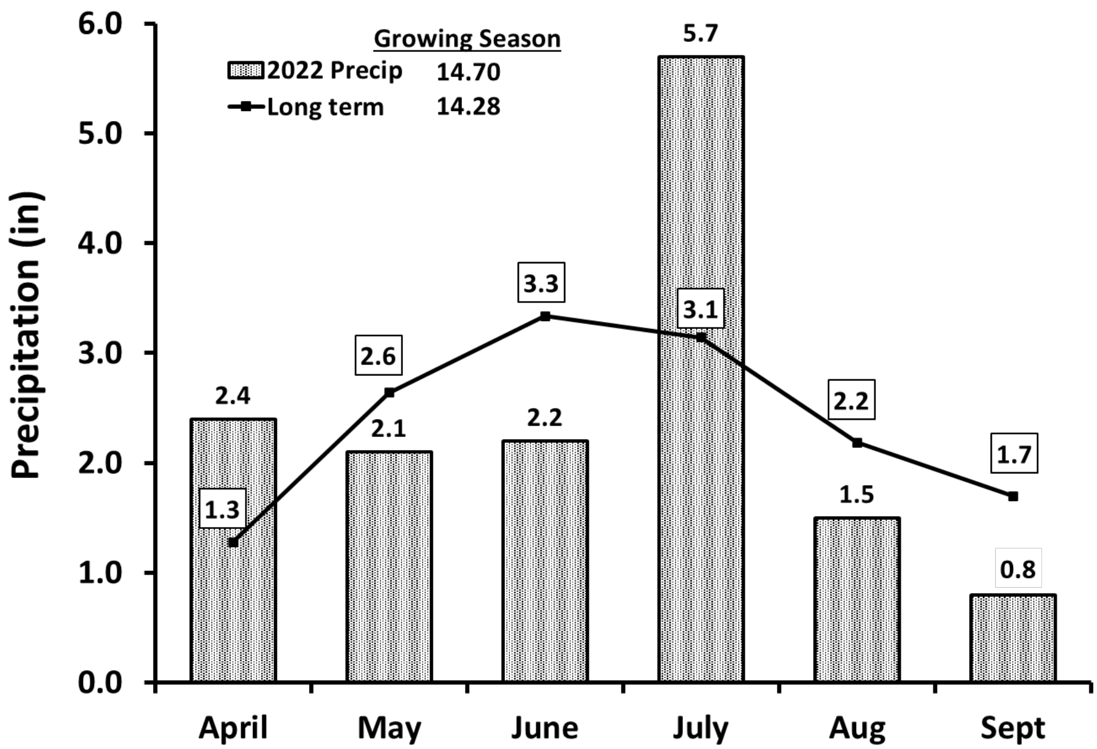
Area IV SCD/ARS Research Farm

Area 4 map



Area 4 Temperature and Precipitation





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, ND VitPro wheat
Previous crop – Sunflowers
05/02/22 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
05/16/22 Field seeded w/JD 1890 30ft drill @ 110 lbs/ac + 70 lbs/ac 11-52-0.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
08/23/22 Field harvested w/JD9650 combine and 30ft. Shellbourne stripper head (29.4 bu/ac).
09/27/22 Field seeded to winter wheat w/JD750 drill @ 90 lbs/ac + 50 lbs/ac 11-52-0.

Field F3, ND Noreen winter wheat
Previous crop – Spring wheat
05/02/22 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.
09/22/21 Field seeded to ND Noreen winter wheat w/JD 1890 30ft drill @ 90 lb/ac + 70 lb/ac 11-52-0.
06/04/22 Contractor sprayed field w/OpenSky @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + ClassAct @ 1 gal/100 gal.
04/30/2 Contractor banded liquid N 27-0-0-1.
Contractor sprayed field
08/10/22 Field harvested w/JD9650 combine and 30ft. Shellbourne stripper head (51.6 bu/ac).

Field F4, Croplan CP455E sunflowers
Previous crop- Winter wheat
05/02/22 Contractor banded liquid N 27-0-0-1 @ 14 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Spartan Charge @ 4 oz/ac + Hellfire @ 2 qt/100 gal.
06/06/22 Field planted 1750 MaxEmerge XP planter @ 24,000 seeds/ac.
07/01/22 Contractor sprayed field w/Express @ 0.5 oz/ac + Shadow @ 7 oz/ac + Destiny @ 64 oz/100 gal + Interlock @ 4 oz/ac.
08/14/22 Contractor aerial sprayed field w/Serpent @ 4.5 oz/ac + Cerium Elite @ 2 oz/ac.
10/28/22 Field harvested w/JD 9650 and all crop head (2613 lb/ac).

Field F5, Koma buckwheat
Previous crop – Corn
05/02/22 Contractor banded liquid N 27-0-0-1 @ 11 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/14/22 Field seeded w/JD 1890 30ft drill @ 50 lb/ac + 60 lb/ac 11-52-0.
07/01/22 Contractor sprayed field w/Poast @ 8 oz/ac + Destiny @ 64 oz/100 gal.
08/31/22 Contractor aerial sprayed field w/Mustang Max @ 2 oz/ac + Cerium Elite @ 2 oz/ac.

09/27/22 Field swathed w/MacDon 128ft swather.
10/12/22 Field harvested w/JD 6620 combine and pickup head (216 lb/ac).

Field F6, ND VitPro spring wheat

Previous crop – Corn
05/02/22 Contractor banded liquid N 27-0-0-1 @ 11 gal/ac.
05/17/22 Field seeded w/JD 1890 30ft drill @ 110 lbs/ac + 70 lbs/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
08/16/22 Field harvested w/JD9650 combine and 30ft. Shellbourne stripper head (43.2 bu/ac).

AREA-G Field Operations
SW ¼ Section 8 T138N R81W

field G1 (former tree plot), Croplan CP2790VP2P corn

Previous crop – Spring wheat
05/02/22 Contractor banded liquid N 27-0-0-1 @ 18 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/02/22 Field seeded w/JD 1750 MaxEmerge XP planter @ 24,000 seeds/ac.
07/01/22 Contractor sprayed field w/Durango @ 32 oz/ac + Status @ 4 oz/ac + Hellfire @ 2 qt gal/100 gal. + Interlock @ 4 oz/ac.
11/02/22 Field harvested w/JD9650 combine and all crop head.

Field G2, Vernal alfalfa

Previous crop – Alfalfa
06/27/22 Field cut w/Case IH 16 ft. augerhead swather.
07/01/22 Field baled by Northland dairy (1.47 T/ac).
08/05/22 Field cut by Northland dairy.
08/10/22 Field baled w/New Holland BR790 baler (1.62 T/ac).

Field G3, ND Vitpro spring wheat

Previous crop – Fallow
05/02/22 Contractor banded liquid N 27-0-0-1 @ 11 gal/ac.
05/25/22 Field seeded w/JD 1890 30ft drill @ 110 lb/ac + 70 lb/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
08/22/22 Field harvested w/JD9650 combine and 30ft. Shellbourne stripper head (42.5 bu/ac).

Field G4, fallow

Previous management – Spring wheat
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.

07/21/22 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + ClassAct @ 2 gal/100 gal.

AREA-H Field Operations
NE ¼ Section 18 T138N R81W

Field H1, Croplan CP2790VP2P corn

Previous crop – Sunflowers
05/02/22 Contractor banded liquid N 27-0-0-1 @ 18 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
05/31/22 Field seeded w/JD 1750 MaxEmerge XP planter @ 24,500 seeds/ac.
07/01/22 Contractor sprayed field w/Durango @ 32 oz/ac + Status @ 4 oz/ac + Hellfire @ 2 qt gal/100 gal. + Interlock @ 4 oz/ac.
11/09/22 Field harvested w/JD9650 combine and all crop head (90.7 bu/ac).

Field H2, ND VitPro spring wheat

Previous crop – Soybeans
05/02/22 Contractor banded liquid N 27-0-0-1 @ 11 gal/ac.
05/18/22 Field seeded w/JD 1890 30ft drill @ 110 lb/ac + 70 lb/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
08/23/22 Field harvested w/JD9650 combine and 30 ft Shellbourne stripper head (37.4 bu/ac).

Field H3 east, Croplan CP455 sunflowers

Previous crop – Buckwheat
05/02/22 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Spartan Charge @ 4 oz/ac + Hellfire @ 2 qt/100 gal.
06/07/22 Field planted 1750 MaxEmerge XP planter @ 24,000 seeds/ac.
07/01/22 Contractor sprayed field w/Express @ 0.5 oz/ac + Shadow @ 7 oz/ac + Destiny @ 64 oz/100 gal + Interlock @ 4 oz/ac.
08/14/22 Contractor aerial sprayed field w/Serpent @ 4.5 oz/ac + Cerium Elite @ 2 oz/ac.
10/27/22 Field harvested w/JD 9650 and all crop head (2251 lb/ac).

Field H3 west, Koma buckwheat

Previous crop – Spring wheat
05/02/22 Contractor banded liquid N 27-0-0-1 @ 11 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/15/22 Field seeded w/JD 1890 30ft drill @ 50 lb/ac + 60 lb/ac 11-52-0.
07/01/22 Contractor sprayed field w/Poast @ 8 oz/ac + Destiny @ 64 oz/100 gal.
08/31/22 Contractor aerial sprayed field w/Mustang Max @ 2 oz/ac + Cerium Elite @ 2 oz/ac.
09/14/22 Field swathed w/MacDon 12 ft swather.
10/14/22 Field harvested w/JD 6620 combine and pickup head (413 lb/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 H4a, Croplan CP0426X soybeans

Previous crop – Corn
05/02/22 Contractor banded liquid N 27-0-0-1 @ 11 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
05/__/22 Field seeded w/JD 1750 MaxEmerge XP planter @ 24,500 seeds/ac.
10/12/22 Field harvested w/JD 6620 combine and 15 ft. flex head (14.1 bu/ac).

Field H4b, ND Noreen winter wheat

Previous crop – Spring wheat
05/02/22 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.
09/22/21 Field seeded w/JD 1890 30ft drill @ 90 lb/ac + 70 lb/ac 11-52-0.
06/04/22 Contractor sprayed field w/OpenSky @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + ClassAct @ 1 gal/100 gal.
08/15/22 Field harvested w/JD9650 combine and 35 ft straight head (52.8 bu/ac).

Field H4c, Durwood peas

Previous crop- Winter wheat
05/__/22 Field seeded w/JD 750 drill @ 350,000 seeds/ac + 50 lb/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
09/08/22 Field harvested w/JD 6629 and 15 ft flex head (24.0 bu/ac).

Field H4d, Croplan CP2790VP2P corn

Previous crop- Peas
05/02/22 Contractor banded liquid N 27-0-0-1 @ 18 gal/ac.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/01/22 Field seeded w/JD 1750 MaxEmerge XP planter @ 24,000 seeds/ac.
07/01/22 Contractor sprayed field w/Durango @ 32 oz/ac + Status @ 4 oz/ac + Hellfire @ 2 qt gal/100 gal. + Interlock @ 4 oz/ac.
11/07/22 Field harvested w/JD9650 combine and all crop head (bu/ac).

Field H5 – LTAR PROJECT (BAU trtmt), VitPro spring wheat

Previous year – Soybeans
05/02/22 Contractor banded liquid N 27-0-0-1 @ 14 gal/ac.
05/24/22 Field seeded w/JD 1890 30ft drill @ 110 lb/ac + 70 lb/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
09/07/22 Field harvested w/JD9650 combine and 35 ft flex head and no straw chopper (41.7 bu/ac).
09/09/22 Field baled w/BR790 New Holland baler (__ T/ac).

AREA-I FIELD OPERATIONS
NE ¼ Section 20 T138N R81W

Field I1, VitPro spring wheat (Continuous spring wheat 37 yrs).

This field will remain as a continuous spring wheat treatment.
05/02/22 Contractor banded liquid N 27-0-0-1 @ 14 gal/ac.
05/19/22 Field seeded w/JD 1890 30ft drill @ 110 lb/ac + 70 lb/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
08/25/22 Field harvested w/JD9650 combine and 30 ft Shellbourne stripper head (38.2 bu/ac).

Field I2 – LTAR project (aspirational trtmt), VitPro spring wheat

Previous crop – Soybeans
05/02/22 Contractor banded liquid N 27-0-0-1 @ 14 gal/ac.
05/23/22 Field seeded w/JD 1890 30ft drill @ 110 lb/ac + 70 lb/ac 11-52-0.
05/26/22 Contractor sprayed field w/RT3 @ 32 oz/ac + Hellfire @ 2 qt/100 gal.
06/27/22 Contractor sprayed field w/Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + Slant @ 4 oz/ac.
08/30/22 Field harvested w/JD9650 combine and 30 ft Shellbourne stripper head (37.3 bu/ac).

Field I3, LTAR plot study

See associated report.

SUMMARY OF AREA IV RESEARCH FARM CROP YIELDS

Field	Crop	Variety	Yield
			(per acre)
F2	Spring Wheat	ND VitPro	29.4 bu
F3	Winter Wheat	ND Noreen	51.6 bu
F4	Sunflowers	Croplan CP455E	2614 lb
F5	Buckwheat	Koma	216 lb
F6	Spring Wheat	ND Vitpro	43.2 bu
G1	Corn	Croplan CP2790VP2P	Not recorded
G2	Alfalfa	Vernal	
		1st Cutting	1.47 T
		2nd Cutting	1.62 T
G3	Spring Wheat	ND Vitpro	42.5 bu
G4	Fallow	--------------------	‘-------
H1	Corn	Croplan CP2790VP2P	90.7 bu
H2	Spring Wheat	ND Vitpro	37.4 bu
H3 East	Sunflowers	Croplan CP455E	2251 lb

Field	Crop	Variety	Yield
H3 west	Buckwheat	Koma	413 lb
H4 (a)	Soybeans	Croplan CP0426X	14.1 bu
H4 (b)	Winter Wheat	ND Noreen	52.8 bu
H4 (c)	Durwood Peas		24.0 bu
H4 (d)	Corn	Croplan CP2790VP2P	88.6 bu
H5	Spring Wheat	ND Vitpro	41.7 bu
I1	Spring Wheat	ND Vitpro	38.2 bu
I2	Spring Wheat	ND Vitpro	37.3 bu

Notes and crop yields were compiled by Robert Kolberg, Jakob Schmid, and Raina Hanley.

Variety Trials – 2022
Hettinger Research Extension

Hard red spring wheat – Mandan

Variety	Plant Height	Plant Lodge	Test Weight	Grain Protein	----- Grain Yield ---- 2020	2021	2022	Average Yield 2 yr	3 yr
	inches	0-9*	lbs/bu	%	------------ Bushels per acre ------------				
AAC Brandon	29	0	60.1	12.3	--	26.5	49.3	37.9	--
AAC Concord	35	0	59.3	12.5	45.5	21.4	54.3	37.8	40.4
AAC Starbuck	29	0	60.1	13.2	--	20.1	51.6	35.9	--
AAC Wheatland VB	30	0	59.3	12.0		22.5	51.2	36.9	--
AP Gunsmoke CL2	30	0	60.4	11.4	45.3	19.8	66.4	43.1	43.8
AP Murdock	28	0	59.2	11.4	44.7	16.7	65.2	41.0	42.2
AP Smith	27	0	59.8	12.1	43.9	23.7	58.5	41.1	42.0
Asend-SD	33	0	60.4	10.8	--	19.7	65.7	42.7	--
Bolles	31	0	60.1	13.4	40.7	18.4	56.5	37.4	38.5
CAG-Justify	31	0	59.2	10.6	--	20.8	67.2	44.0	--
CAG-Reckless	31	0	61.3	11.3	--	19.0	57.9	38.4	--
CAG-Recoil	29	0	60.3	11.2	--	--	66.6	--	--
CP3099A	34	0	59.6	10.8	--	15.1	62.8	38.9	--
CP3188	31	0	58.7	10.7	--	24.3	58.7	41.5	--
CP3530	32	0	60.9	11.4	45.9	19.1	58.4	38.7	41.1
Dagmar	30	0	60.1	11.5	40.5	18.8	57.7	38.2	39.0
Driver	31	0	61.0	11.7	50.7	23.3	57.0	40.1	43.7
Faller	32	0	59.5	11.1	48.3	23.4	61.2	42.3	44.3
Glenn	32	0	62.2	11.8	42.0	19.1	54.6	36.9	38.6
Lanning	29	0	59.4	12.0	47.4	22.4	56.0	39.2	41.9
LCS Ascent	29	0	60.4	11.0	--	--	54.9	--	--
LCS Buster	32	0	59.5	9.7	54.0	22.2	69.5	45.9	48.6
LCS Cannon	28	0	61.0	11.5	41.5	18.1	56.6	37.3	38.7
LCS Dual	29	0	60.3	11.1	--	--	55.1	--	--
LCS Hammer AX	29	0	60.0	11.4	--	--	62.8	--	--
LCS Rebel	33	0	61.4	12.7	46.8	17.1	58.5	37.8	40.8
LCS Trigger	32	0	61.7	9.4	50.2	22.2	70.4	46.3	47.6
MN Rothsay	27	0	59.9	11.0	50.5	20.5	63.5	42.0	44.8
MN Torgy	31	0	61.2	11.2	48.2	21.4	65.7	43.5	45.1
MN Washburn	30	0	60.2	11.6	40.4	20.8	58.1	39.5	39.8
MS Barracuda	28	0	60.2	11.8	43.6	12.1	57.3	34.7	37.7
MS Charger	29	0	59.7	10.6	--	--	61.6	--	--

Variety	Plant Height	Plant Lodge	Test Weight	Grain Protein	2020	2021	2022	2 yr	3 yr
MS Cobra	28	0	60.4	12.2	--	17.1	62.1	39.6	--
MS Ranchero	35	0	61.1	10.4	49.1	27.0	64.3	45.7	46.8
ND Frohberg	31	0	61.2	11.9	45.2	18.8	57.9	38.3	40.6
ND Heron	29	0	61.3	11.8	43.4	15.5	54.2	34.9	37.7
ND VitPro	30	0	61.3	12.3	46.1	16.8	51.1	33.9	38.0
Shelly	29	0	59.8	10.7	--	--	60.9	--	--
SK Rush	33	0	59.4	11.6	--	24.3	57.0	40.6	--
SY 611 CL2	28	0	60.6	11.7	44.3	20.0	60.7	40.4	41.7
SY Ingmar	28	0	60.7	12.6	39.9	21.5	54.3	37.9	38.6
SY Longmire	28	0	60.7	12.0	45.1	19.6	55.2	37.4	40.0
SY McCloud	30	0	61.6	12.4	41.5	17.5	59.8	38.7	39.6
SY Valda	28	0	60.4	11.0	51.5	21.4	60.8	41.1	44.6
TCG Heartland	27	0	60.2	12.0	42.1	15.4	51.0	33.2	36.2
TCG Sptifire	30	0	60.0	11.4	48.7	25.5	63.5	44.5	45.9
TCG Wildcat	30	0	60.8	11.6	38.9	21.6	63.9	42.8	41.5
WB9590	26	0	58.1	11.8	--	17.5	57.2	37.3	--
Trial Mean	30	0	60.2	11.5	44.8	20.3	59.4	39.6	41.6
C.V. %	3.4	--	0.7	4.0	14.0	7.2	6.5	--	--
LSD 5%	1.2	--	0.5	0.6	8.8	3.0	4.5	--	--
LSD 10%	0.9	--	0.4	0.5	7.4	2.5	3.5	--	--

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

Planting Date: May 18

Harvest Date: August 30

Previous Crop: Soybean

Soybean – Roundup Ready – Mandan

Company/ Brand	Variety	Maturity	Plant Height	Test Weight	Seed Oil	Seed Protein	Seed Yield		
							2022	2-Yr	3-Yr
			inches	lbs/bu	%	%			
NDSU	ND21008GT20	00.8	22	53.6	17.9	32.3	42.0	--	--
NDSU	ND17009GT	00.9	21	56.4	17.8	35.2	40.7	34.2	35.7
Xitavo	XO 0101E	0.1	19	53.0	17.2	33.3	42.2	--	--
Proseed	XF 30-12	0.1	22	53.8	17.2	32.4	46.9	--	--
Xitavo	XO 0213E	0.2	22	53.8	17.7	32.7	42.7	--	--
Proseed	XT 80-20N	0.2	23	55.1	16.8	32.9	48.3	--	--
Xitavo	XO 0311E	0.3	21	54.1	17.2	32.5	46.2	--	--
Proseed	EL 30-33	0.3	22	53.3	18.0	32.1	41.9	--	--
Proseed	XT 60-40N	0.4	21	55.4	17.9	32.6	44.7	35.1	34.1
Proseed	XF 30-42N	0.4	22	55.0	17.8	33.4	49.8	--	--
Xitavo	XO 0573E	0.5	19	55.2	17.0	34.2	40.2	--	--
Xitavo	XO 0602E	0.6	20	57.0	16.1	34.3	43.8	--	--
Xitavo	XO 0731E	0.7	21	56.7	16.9	33.7	48.2	--	--
NDSU	ND2108GT73	0.8	21	56.1	17.6	32.2	48.4	40.1	39.4
Trial Mean			21	54.9	17.3	33.2	44.9	36.5	36.4
C.V. %			6.4	1.0	1.9	1.4	8.1	--	--
LSD 5%			2.7	0.6	0.4	0.5	4.4	--	--
LSD 10%			1.9	0.5	0.3	0.4	3.4	--	--

Planting Date: **May 18**
Harvest Date: **October 6**
Previous Crop: **Spring Wheat**

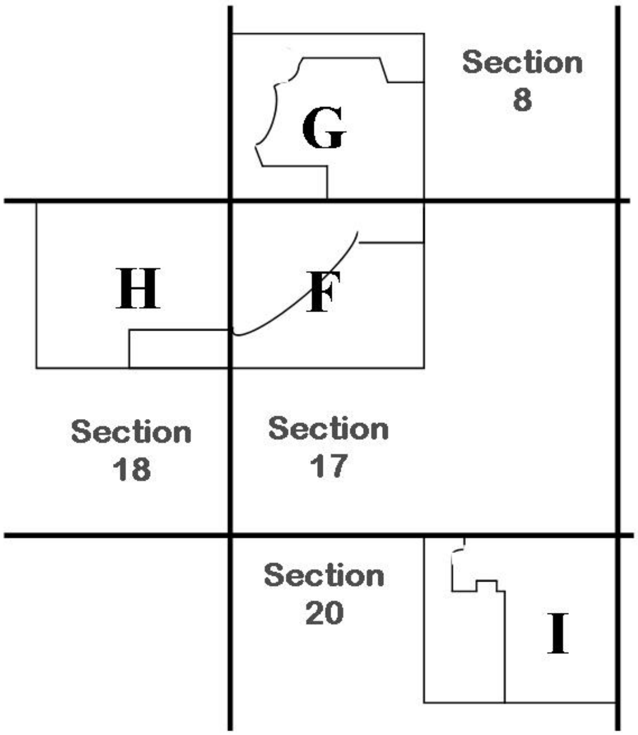
NOTES

Cooperative Research Farm

Area IV Soil Conservation Districts*

USDA-Agricultural Research Service

Founded 1983



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