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INTEGRATOR

https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/

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

Dr. John Hendrickson

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

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

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

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

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

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

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

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In This Issue:

Message from Dave

Dr. David Archer, Research Leader

Integrating crop and livestock production has potential to improve sustainability of agriculture by making more efficient use of inputs, recycling nutrients, reducing need for pesticides, and improving soils. However, while our research on integrated crop livestock (ICL) systems has shown some improvements including increases in soil carbon (see the Liebig et al. story p. 6), there is still a need for further improvement. Other research had indicated potentially more significant benefits with the inclusion of perennials in the system, not only locally (February 2020 Integrator, p. 9 https://www.ars.usda.gov/ARSUserFiles/30640500/INTEGRATOR/Feb2020.pdf) but globally (August 2020 Integrator, p.5 https://www.ars.usda.gov/ARSUserFiles/30640500/INTEGRATOR/August2020.pdf). Accordingly, we have included alfalfa into our dynamic crop rotation at the Area 4 SCDs Cooperative Research Farm. Alfalfa for hay has been a profitable crop in the rotation, in part because there are livestock producers in the area, and we have a good nearby buyer for high quality hay. However, harvesting and selling the hay means that nutrients are being exported from the field. So ideally, the perennials could be grazed or fed in the field retaining the nutrients on-site, as we do in our current long-term ICL study. In addition, previous research showed greater soil benefits if grasses were included in the perennial mix (February 2020 Integrator, p.9), and with greater soil and annual crop production benefits if the perennials were grown for 4-5 years. Our current ICL study includes a brief (1.5 year) perennial phase that includes grasses and legumes within an annual crop rotation. But, given the short duration, we are likely not getting the full benefits of the perennials. Finally, in the cover article by John Hendrickson (p. 1), a review of existing ICL studies indicated a gap in existing studies in integrating the social aspects of these systems with the environmental and economic aspects. We are planning the next phase of our ICL study and will be looking for ways to better incorporate perennial in the system and also integrate the social aspects of these systems. With this in mind, we will be looking for input on direction for the next phase of the study. Please let us know if you are interested in providing input.

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2021 Farming & Ranching for the Bottom Line: Linking Soil to Well-Being

Registration is now open for the February 23 and 24, 2021, "*Linking Soil to Well-Being*", the annual Farming and Ranching for the Bottom Line event anually held in Bismarck, ND. Please invite all your contacts to join us!

Due to the pandemic, this year's event will be held online. The event begins at 9:00 am on Tuesday, February 23, and continues at 8:55 a.m. Wednesday, February 24, 2021.

Just two of the 14 speakers for the February 23 and 24, 2021, event are Dr. Nicole Van Dam and John Kempf.

Dr. Nicole Van Dam: Van Dam is a professor at the Friedrich-Schiller University, Jena, Germany, and a researcher at the German Centre for Integrative Biodiversity Research, Leipzig, Germany. Her research mission is to unravel the molecular and chemical mechanisms governing interactions between plants and herbivores.

John Kempf: Kempf is the founder of Advancing Eco Agriculture (AEA), a plant nutrition and biostimulants consulting company. He is a top expert in the field of biological and regenerative farming. Kempf founded AEA in 2006 to help fellow farmers by providing the education tools and strategies that will have a global effect on the food supply and those who are growing that supply. He is building a comprehensive systems-based approach to plant nutrition, a system solidly based on the sciences of plant physiology, mineral nutrition and soil microbiology.

Please see the flyer on the next page for the full list of speakers and their speaking times. Complete speaker bios are found at https://www.area4farm.org/conference (scroll to the page bottom).

There is **no cost** to participate in this online event. However, registration is required to get the link for the event. Those who register will be e-mailed the link the week of the event.

Register online at **https://farming-and-ranching-for-the-bottom-line.eventbrite.com**.

If you have any questions on registration or the event, contact Cal Thorson, USDA-ARS Technical Information Specialist at: cal.thorson@usda.gov or 701.527.3795.

Farming and Ranching for the Bottom Line

Linking Soil to Well-Being

February 23 & 24, 2021 | Online via Zoom

DAY 1: Tuesday, Feb 23

9:00 Welcome

9:15 Area 4 Farm: Benefits of Diversity and Stored Soil Moisture in 2020
David Archer

9:45 Plant Diversity Affects Shoot Metabolomes by Changing the Soil Community
Nicole van Dam, German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig

10:45 Farming Systems, Environment, and Food Quality
Andrea Clemensen

11:05 Root-Soil Factors that Influence Crop and Forage Quality
Mike Grusak

11:25 Healthy Soil, Healthy Food, and Healthy People: Linking the Phenomes
Matt Picklo

11:45 Soil Microbial Networks and Agroecosystem Functioning
Samiran Banerjee

12:00 Lunch Break/Virtual Posters

1:00 Addressing the Sustainability of Agriculture
John Reganold, Washington State University

2:00 Pasture Management Effects on Copper Utilization in Growing Heifers
Rachael Christensen

2:20 Human Health and Chemical Compounds in Grass-fed and Grain-fed Meat and Dairy
Stephan Van Vliet, Duke Molecular Physiology Institute

2:50 Wrap-up and Introduction to Day 2

3:00 Discussion Rooms
Room 1: Cropping Systems, Room 2: Grazing Systems

DAY 2: Wednesday, Feb 24

8:55 Welcome

9:00 Reducing Fertilizer Use
John Kempf, Advancing Eco Agriculture

10:30 Break

10:45 Innovative Producer Panel: Bringing Life Back to the Farm Using Bioinoculants
Derek and Tannis Axten
Chris Teachout

12:00 Lunch Break/Virtual Posters

1:00 Water Use Efficiency
John Kempf

2:00 What's Going on at the Menoken Farm?
Darrell Oswald

2:30 Break

2:45 Using Inoculants Effectively
John Kempf

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Area Four Research Farm	ND Grazing Lands Coalition
Bismarck State College	NDSU Extension
Burleigh County Soil Conservation District	NDSU Research Extension Centers
Menoken Farm	USDA Agricultural Research Service
Morton County Soil Conservation District	USDA Natural Resources Conservation Sevice

REGISTRATION: There is no cost to attend this event, but preregistration is required at https://farming-and-ranching-for-the-bottom-line.eventbrite.com.
If you have any questions, contact Connie Bryant at constance.bryant@nd.nacdnet.net or at 701-250-4518, ext. 3.
Zoom link will be emailed out the week of the event.
Visit area4farm.org for more information.

This flyer and these workshops are based upon work supported by USDA and the North Dakota University System.

Ecological Implications of Plant Secondary Metabolites – Enhancing Agricultural Sustainability Through Plant Biochemical Diversity

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

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

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

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

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

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

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

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

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

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

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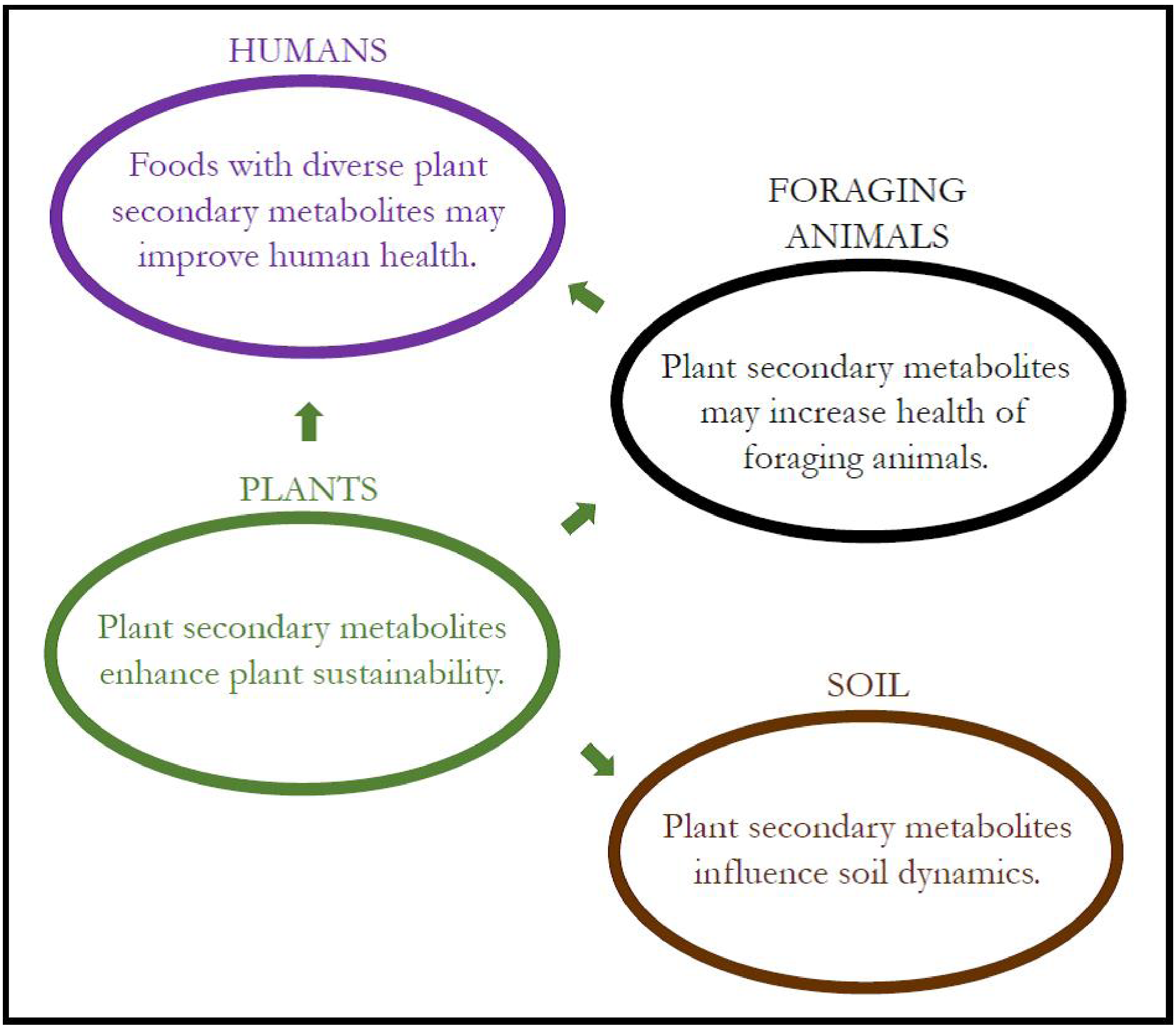
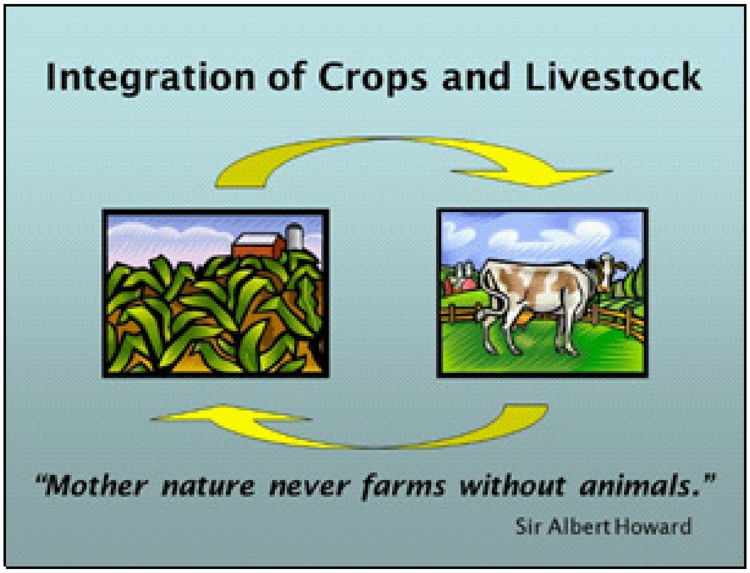


Integrated Crop-Livestock Systems and Soil Carbon: The Importance of Grazing and Residue Retention

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



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

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

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

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

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

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

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

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

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

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

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

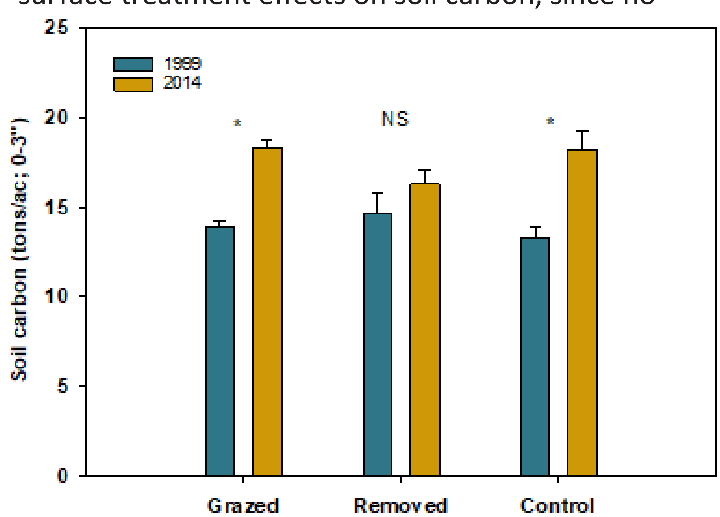


Figure 1. Soil carbon at 0-3" for integrated crop-livestock treatments differing in residue management (residue grazed, removed, or retained as a control). Stars (*) above bars signify a significant change in soil carbon between 1999 and 2014 (P<0.1). NS indicates the difference was not significant.

Collecting samples for soil carbon measurements

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

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

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

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

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New Faces

Emma Bergh

Emma Bergh, Biological Science Laboratory Technician, is originally from Massachusetts. She has a bachelor's degree in biology from Oberlin College in Ohio. During her undergrad, she spent a summer working at the Missouri Botanical Garden, where she was involved in research on potential perennial legume crops. For the past two years, she has worked as a lab tech in a fruit fly genetics lab at Indiana University. In her free time, she enjoys hiking, reading, playing board games with friends, and taking care of her many houseplants.

Simple Organic Compounds Related to Benzoic Acid may Affect the Amount of Nitrogen Bound to Manure Fiber.

Drs. Jonathan Halvorson, Scott Kronberg, Rachael Christensen, David Archer, and Ann Hagerman, Chemistry & Biochemistry, Miami University, Oxford, OH

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

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

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

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

Chemical analyses were conducted on diet components and untreated manure samples by a commercial lab (Ward Laboratories Inc., Kearney, NE). Total soil C and N was determined by dry combustion using a LECO FP-2000 CN analyzer (LECO Corporation, St. Joseph, MI). The concentrations of total P (P2O5), K (K_2O), S, Ca, Mg, Na, Zn, Fe, Mn, Cu, and B in feed and manure were determined by Inductively Coupled Argon Cooled Plasma Spectrometry (ICAP, Thermo) after acid digestion of samples.

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

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

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

Figure 1

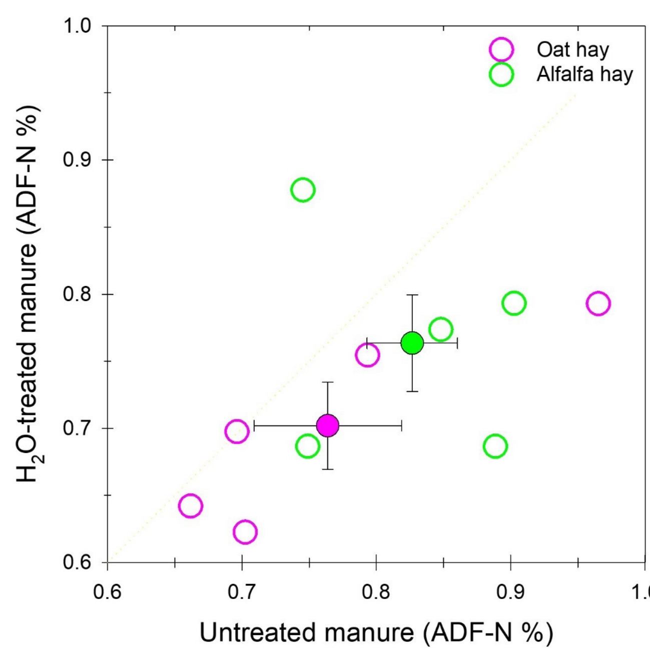

Figure 1. Manure ADF-N (%) for individual cows (open symbols). Samples were analyzed after treatment with water or without treatment (sample handling only). Filled symbols indicate arithmetic mean values (n=5). Error bars indicate the standard error of the mean. The same five animals were used to produce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

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

Significant treatment effects on manure ADF-N were complex, influenced by diet, compound, and concentration. For example, alfalfa hay resulted in manure in which ADF-N concentration was positively related to the number of OH functional groups on the phenolic treatment compounds (B1-B3 in Figure 2a), but this pattern was observed only at the highest (0.1 M) concentration. At other concentrations, the relationship between ADF-N and OH functional groups was inconsistent.

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

This work suggests that secondary plant compounds might indirectly influence nutrient cycling in integrated crop livestock systems. Manure ADF-N, affected by solution concentration and varying by treatment suggest that some of changes to manure

Figure 2a

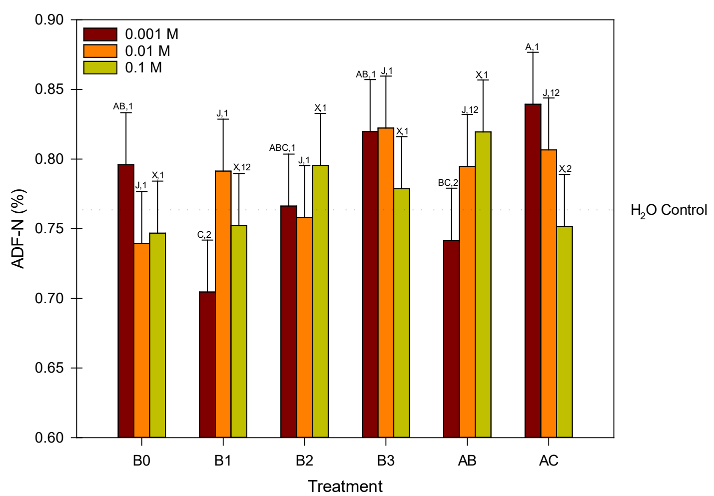

Figure 2b

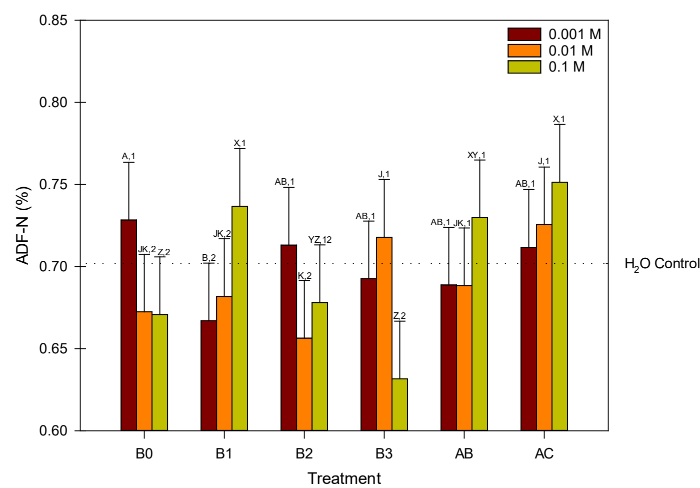

Figure 2. Manure ADF-N (%) for cows fed a) alfalfa hay, and b) oat hay mixed ration. For each diet, we applied a linear mixed model using PROC GLIMMIX to examine the influence of treatment compound (TRT) and concentration (CONC) on ADF-N. Both TRT and CONC were classed as fixed effects while animals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

but this pattern was observed only at the lowest (0.001 M) treatment concentration. No treatment differences were observed for the other concentrations.

In contrast, the oat hay ration resulted in manure in which ADF-N concentration was negatively related to the number of OH functional groups on the phenolic treatment compounds (B1-B3 in Figure 2b) composition associated with dietary tannins or related phenolic compounds do not depend on rumen fermentation and subsequent digestion. Mineralization kinetics of manure may be impacted by increasing or decreasing the amount of nitrogen bound to manure fibers but if our observations are true in a broader sense, effects of simple organic compounds on ADF-N may also affect estimates of heat damaged protein typically included in forage analyses.

Table 1. Feed analysis[a]

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

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

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

Table 2. Manure composition[a]

	Cow	***pH$_w$***	***DM***	***N$_{tot}$***	***N$_{org}$***	***P$_2$0$_5$***	***K$_2$0***	***S***	***Ca***	***Mg***	***Na***	***Zn***	***Fe***	***Mn***	***Cu***	***B***
				--------------------%--------------------								--------Mg kg^{-1}--------				
	A	5.5	94.3	2.44	2.37	0.86	0.71	0.21	0.41	0.38	0.16	99	386	82	7	7
	B	8.8	94.2	1.98	1.96	1.02	2.51	0.25	0.56	0.35	0.58	105	329	84	8	10
	C	8.2	93.9	2.04	2.02	0.63	0.96	0.23	0.52	0.40	0.54	137	694	134	17	8
	D	8.8	93.8	2.50	2.48	0.91	1.13	0.29	3.37	0.76	0.24	107	1331	142	19	33
	E	8.1	94.5	2.06	2.03	0.86	1.62	0.23	0.57	0.40	0.17	87	343	91	6	10
	Avg.	**7.9**	**94.1**	**2.20**	**2.17**	**0.86**	**1.39**	**0.24**	**1.09**	**0.46**	**0.34**	**107**	**617**	**107**	**11**	**14**
	SEM	0.6	0.1	0.11	0.11	0.06	0.32	0.01	0.57	0.08	0.09	8	191	13	3	5
Diet 1[b]	CV %	17	<1	11	11	17	51	13	118	37	61	17	69	27	55	80
	A	8.5	95.1	2.52	2.50	0.67	1.19	0.30	2.81	0.72	0.20	86	1140	142	19	36
	B	8.6	94.3	2.16	2.16	0.81	0.75	0.28	2.93	0.55	0.17	103	1559	155	17	30
	C	9.0	94.1	2.12	2.11	1.06	0.67	0.24	3.05	0.71	0.12	92	1453	122	15	27
	D	7.8	94.8	2.02	2.01	0.82	1.44	0.24	0.48	0.35	0.35	80	348	76	7	8
	E	8.9	94.6	2.03	2.03	1.16	0.69	0.29	3.07	0.73	0.09	101	1803	160	20	28
	Avg.	**8.6**	**94.6**	**2.17**	**2.16**	**0.90**	**0.95**	**0.27**	**2.47**	**0.61**	**0.19**	**92**	**1260**	**131**	**16**	**26**
Diet 2[b]	SEM	0.2	0.2	0.09	0.09	0.09	0.16	0.01	0.50	0.07	0.05	5	252	15	2	5
	CV %	6	<1	9	9	22	37	10	45	27	54	11	45	26	32	41

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

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

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Forage Economics Calculator – a Web Tool

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

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

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

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

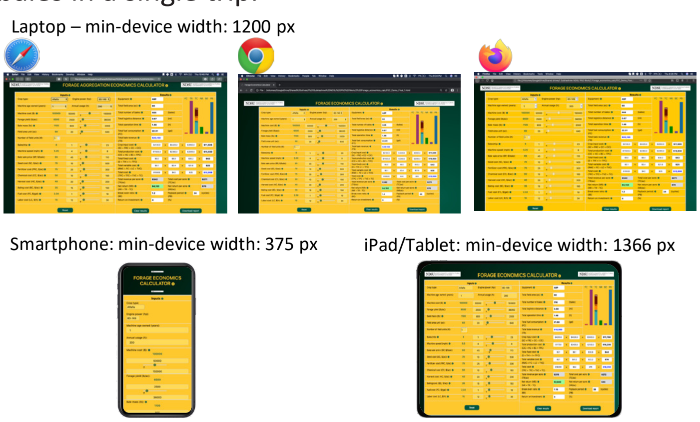

Figure 1. Forage economics calculator web tool is compatible across web browsers and device screen sizes.

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

The forage economics web tool consists of three main sections: (i) home, (ii) user instructions & manual, and (iii) calculator section. The first section is the

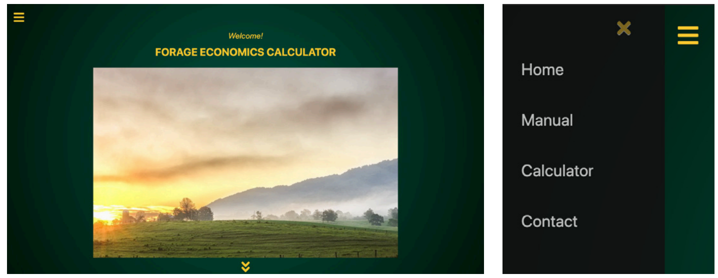

Figure 2. Home/welcome page of the forage economics calculator web tool (left). A collapsible navigation sidebar enables a smooth transition between sections (right).

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

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

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

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

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

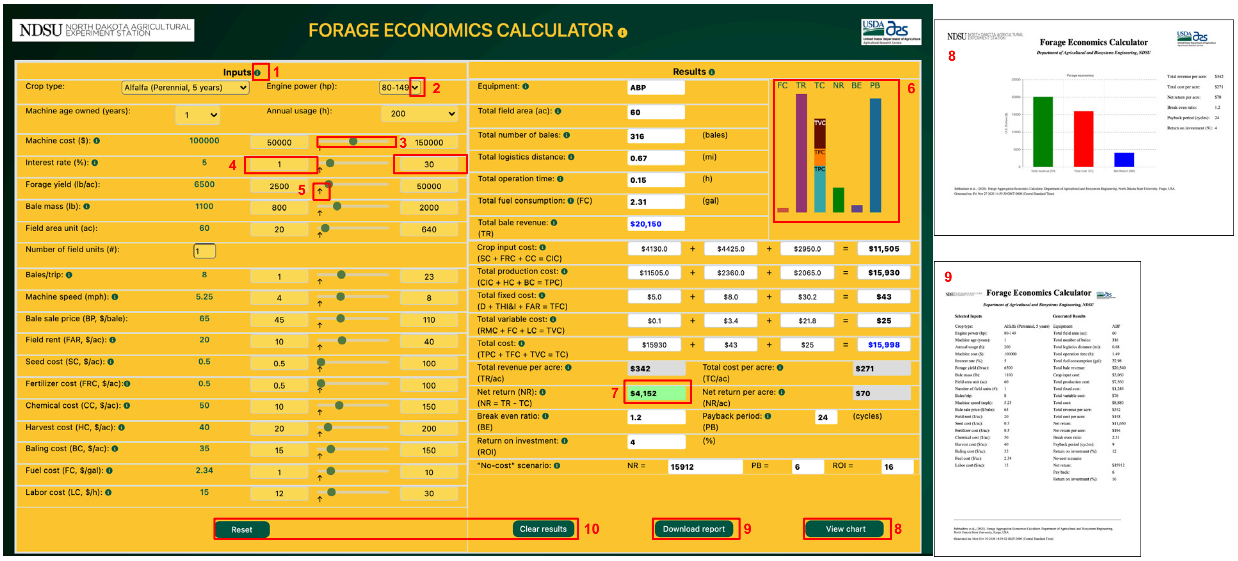

Figure 4. Calculator section contains 21 inputs and 23 output results including a dynamic and downloadable chart and report

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

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

5. Markers below sliders provide sensitivity analysis.

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

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

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

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

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

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

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

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

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

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Can time of grazing reduce Kentucky bluegrass in your pastures?

Drs. John Hendrickson and Scott Kronberg

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

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

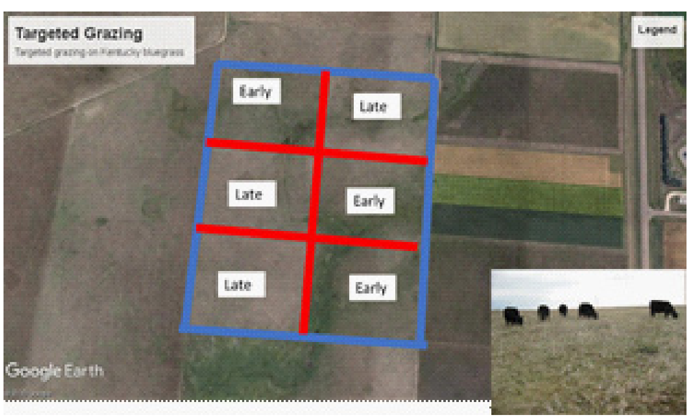

Figure 1. The layout of the pastures used in the study. The pastures were split in half and each half was assigned to either an Early or a Late grazing treatment. The inset shows cattle grazing on the Early grazed treatments.

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

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

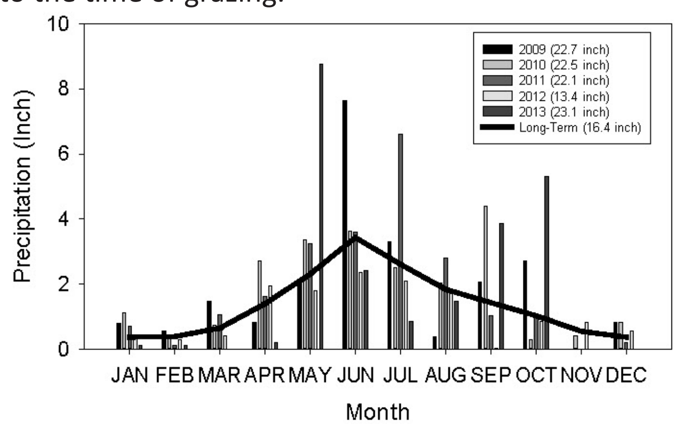

Figure 2. Monthly precipitation by year (bars) of the study and long-term average for NGPRL (Line).

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

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

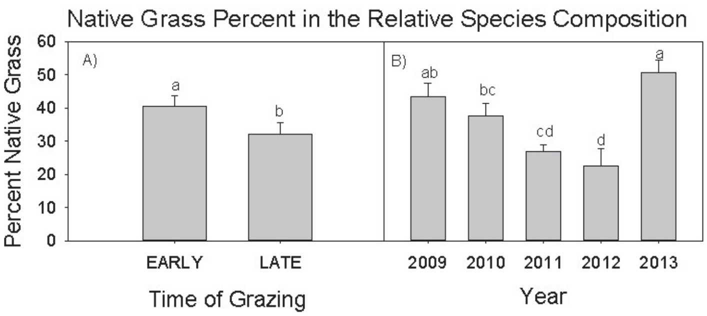

Figure 3. The percent of the rangeland vegetation made up of native grasses for the Early and Late treatments and for each year.

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

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

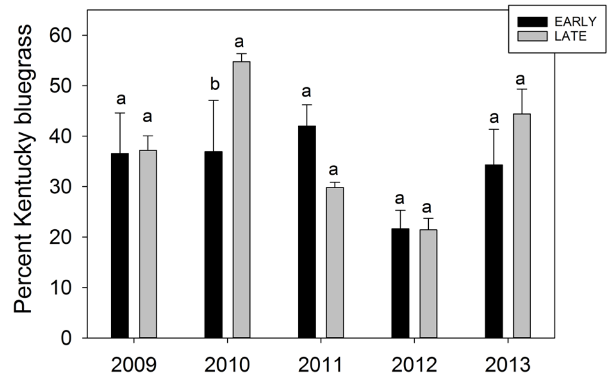

Figure 4. Impacts of grazing treatment on the amount of Kentucky bluegrass in the rangeland vegetation.

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

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

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ARS Scientists use Soil Archives to Examine Patterns of Water-Extractable Soil Organic Matter Associated with Long-Term Soil Change in the Great Plains

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

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

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

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

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

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

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

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

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

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

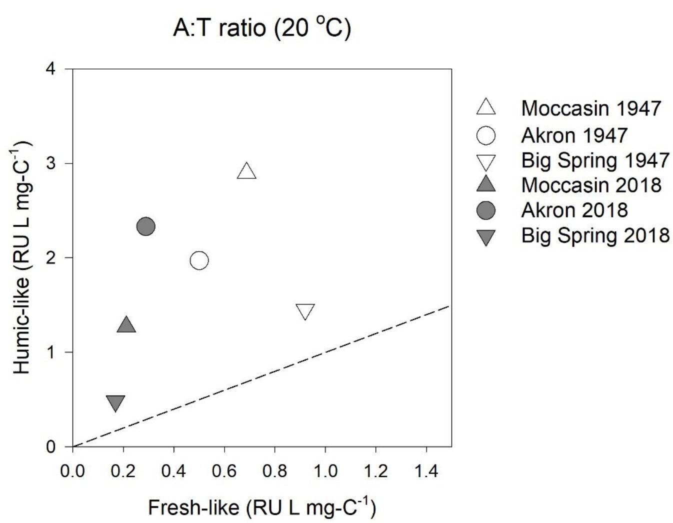

Figure 1. The proportion of stable "Humic" soluble organic matter to more recent "Fresh" organic matter in soil varies with location and sample date.

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Influence of Big Data on Agricultural Practices

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

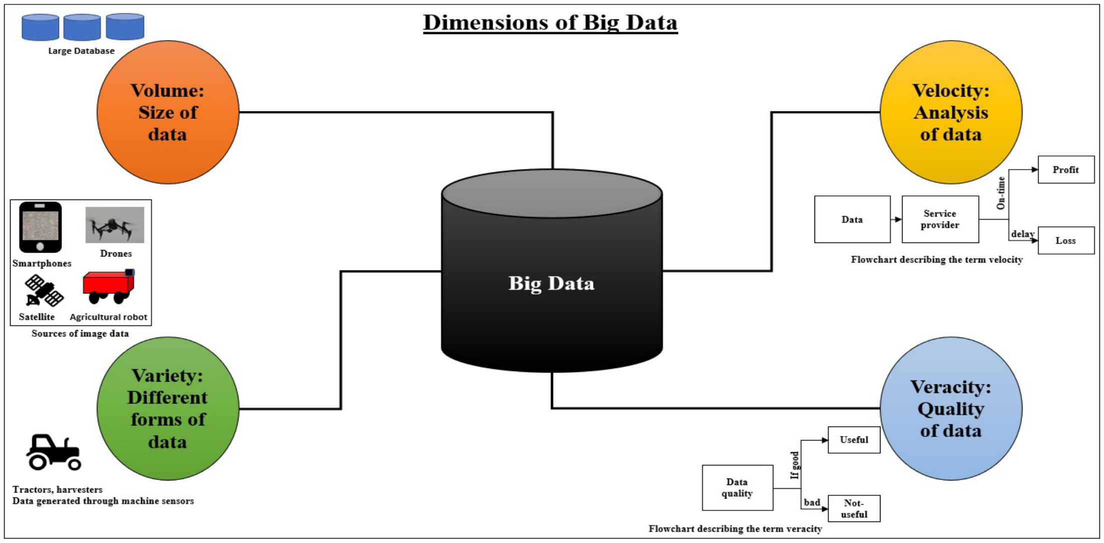

Figure 1. Dimensions of big data showing its characteristics.

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

Characteristics of big data and potential agriculture use

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

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

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

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

4. Veracity: quality and potential use of data.

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

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

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

Flow of big data

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

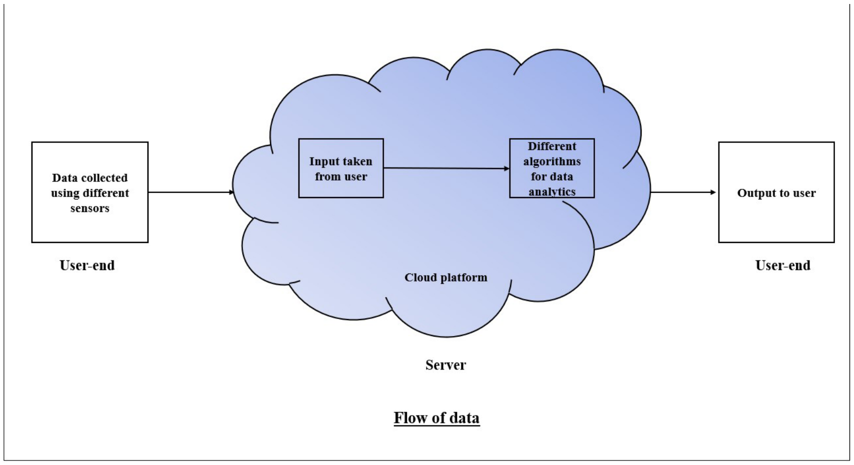

Figure 2. Flow of big data from users to processing and results back to users.

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

Benefits of employing big data in agriculture

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

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

Challenges

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

Big data product illustration - Plantix

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

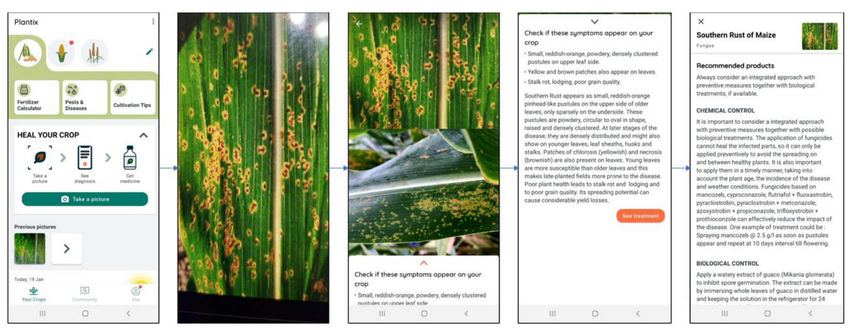

Figure 3. Plantix application interface – a big data illustration.

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

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Integrating Perennial Forages into Annual Cropping Systems: Influence on Soil and Grain Quality

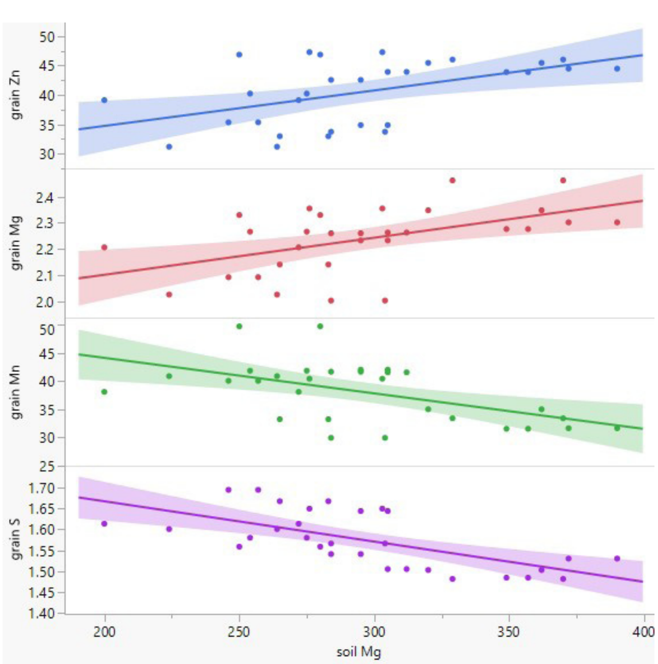
Drs. Andrea Clemensen, Mark Liebig, Michael Grusak, Sara Duke, José Franco, John Hendrickson, and David Archer

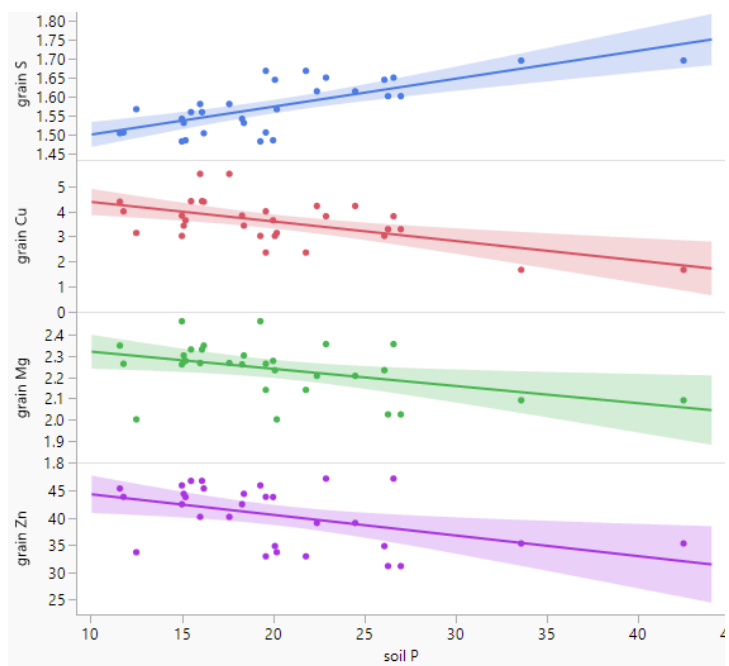
Image 1. Plots showing field study

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

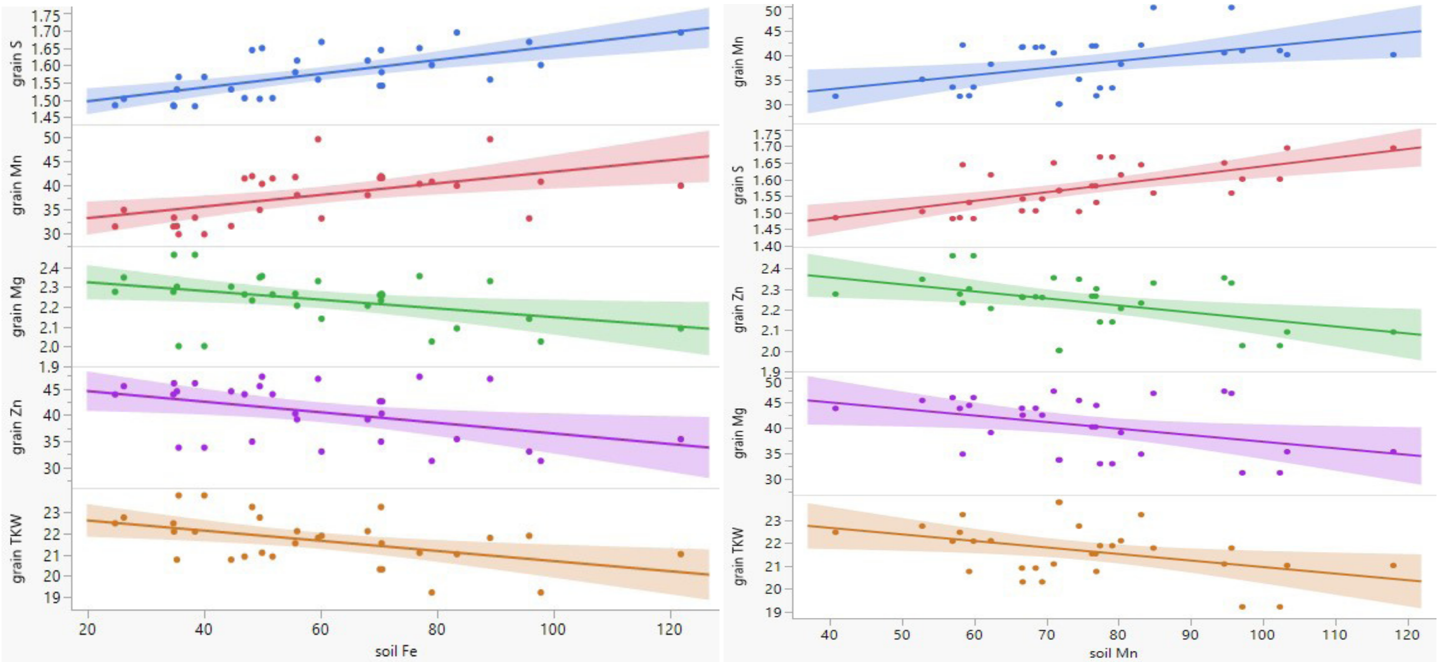
We focused on wheat grain samples from spring wheat planted following 2-5 years of three different perennial treatments; 1- alfalfa, 2- intermediate wheatgrass, and 3- alfalfa / intermediate wheatgrass mixture. No fertilizers were applied to wheat that was planted, after the perennial forages were terminated.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

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

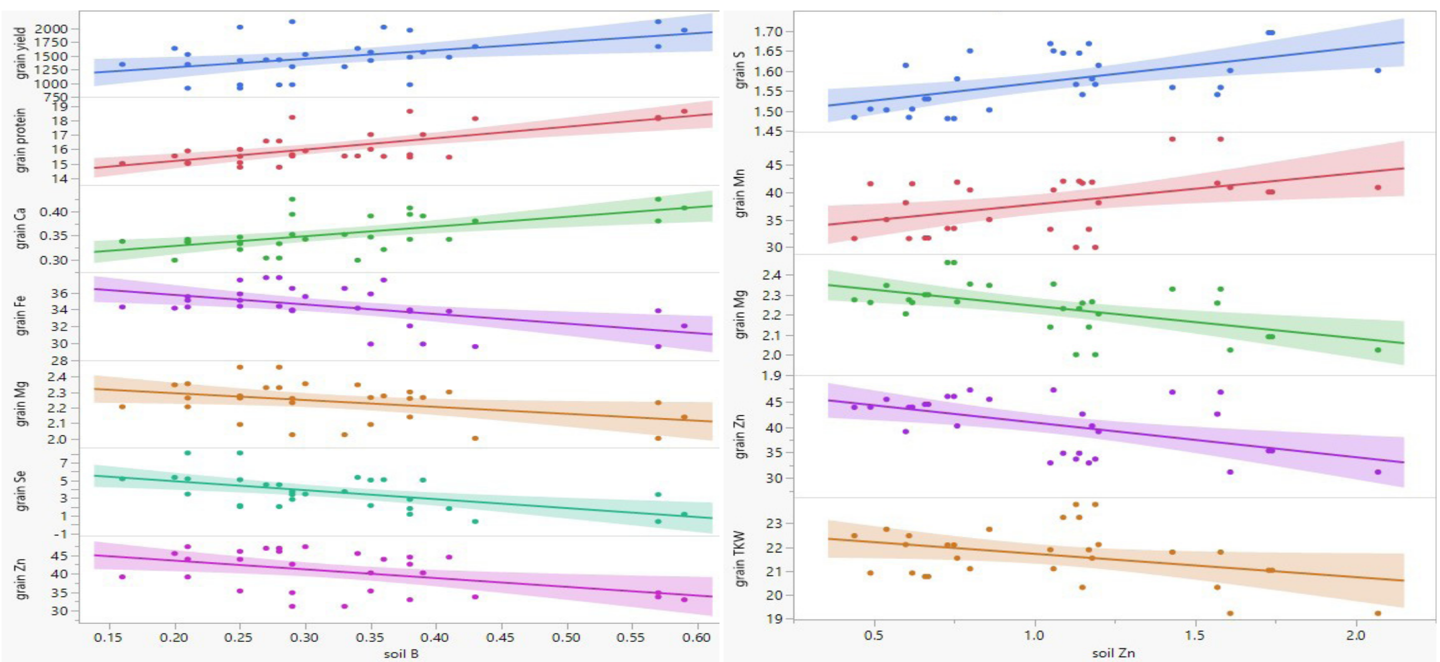




Figures 1 & 2. Relationships showing, on a dry weight basis, grain mineral concentrations Zn, Cu, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}) with increasing soil magnesium or soil phosphorous (µg g^{-1}).



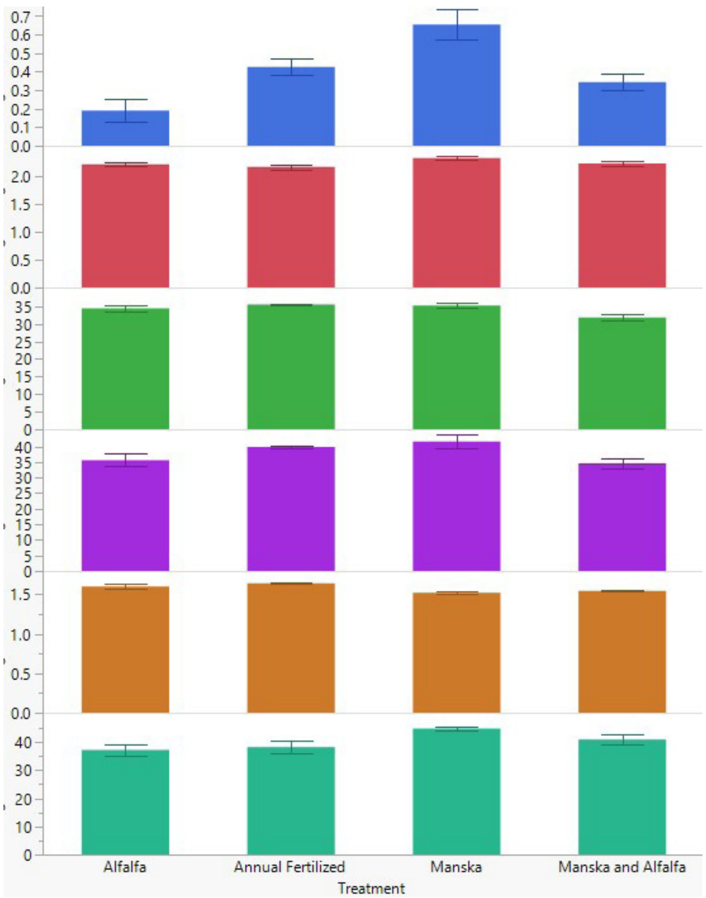
Figures 3 & 4. Relationships showing TKW (thousand kernel weight) and mineral concentrations Zn, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}) with increasing soil iron or soil manganese (µg g^{-1}).

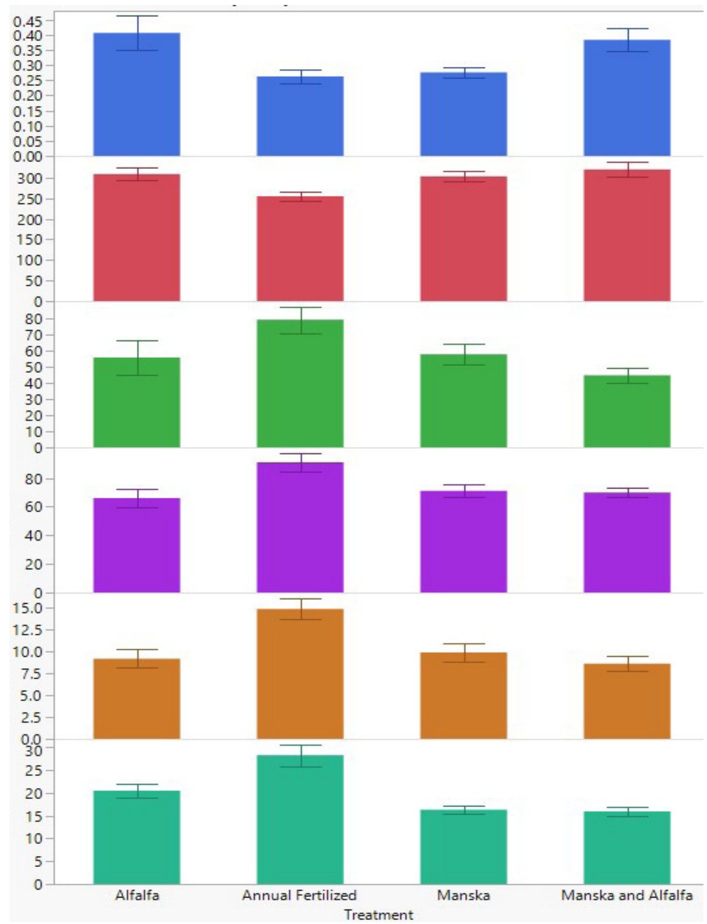


Figures 5 & 6. Relationships showing grain yield (kg ha^{-1}), TKW (thousand kernel weight), protein concentration (%), and mineral concentrations Fe, Se, Zn, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}) with increasing soil boron or soil zinc (µg g^{-1}).

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

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





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

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

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

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Presentations of NGPRL science

Since the last issue:

Mr. Greg Ibach and Dr. David Archer in the meeting

USDA Under Secretary visit On October 9th, Mr. Greg Ibach, USDA Under Secretary Agricultural Marketing and Regulating Program visited the Northern Great Plains Research Laboratory and met with the scientists and members of the NGPRL Customer Focus Group to discussed issues.

Bismarck Start College Soils Classes virtual tours On November 5th, Dr Mark Liebig led the students of Dr. Marco Davinic's Soil Science on virtual tours of the soil research facilities at the Northern Great Plains Research Laboratory.

Low pH Soils Discussed at DIRT Workshop On December 9th, Dr. Mark Liebig and Ryan Buetow (NDSU-Dickinson) discussed the challenges of managing low pH soils at the Dakota Research Innovation and Technology (DIRT) virtual workshop.

American Society of Agronomy, Crop Society of America, and Soil Society of America Presentations The Tri-societies (American Society of Agronomy, Crop Society of America, and Soil Society of America) held their 2020 annual conference virtually on November 10-13. Dr. David Archer presented a seminar entitled, "*Rainfed cropping system productivity and economics in the northern Great Plains*". The paper was co-authored by Mark Liebig and Jay Halvorson. Dr. Jonathan Halvorson presented "*Patterns of Water-Extractable Soil Organic Matter Revealed from the Haas Soil Archive*", which is profiled on page 15. The paper was co-authored by Drs. Mark Liebig,and Angela, California Water Science Center USGS Sacremento, CA. Dr. John Hendrickson presented a poster entitled *'Feasibility of Growing Annuals in an Existing Alfalfa Stand'* with Dave Archer, Andrea Clemensen, Mark Liebig and Rachael Christensen also as authors**.** Dr. Andrea Clemenson presented a poster, *"Integrating Perennial Forages into Annual Cropping Systems: Influence on Soil and Grain Quality".* It is profiled on page 18*.*

Ecological Society of America On August 3-6, Dr. David Toledo presented, *"Biodiversity in Agroecosystems: Win, Lose, or Draw?*"at Ecological Society of America virtual meetings. Coauthors are Amanda Bentley Brymer, Mike Sorice, John Hendrickson, David Archer Dr. John Hendrickson presented a poster entitled *"How do ecological site, year and herbivory interact to impact tiller demography on a native C3 perennial grass in a mixed grass prairie?"*. Coauthors were Johnson, P.S., Xu, L. Sedivec K. Liebig MA, Garrett, J. Igathinathane, C., and Halvorson, G. Johnson and Xu are from South Dakota State, Sedivec is from NDSU and Garrett and Halvorson are from Sitting Bull College. Dr. Andrea Clemenson also presented a poster, "*Perennial Forages Influence Mineral Quality in Annual Cropping Systems".* Coauthors were M.A. Grusak, S.E. Duke, J.R. Hendrickson, J.G. Franco, D. W. Archer, J. N. Roemmich, and M. A. Liebig

North Dakota Stockmen's Association On December 2nd, Drs. Igathi Cannayen and John Hendrickson, along with Subhashree N Srinivasagan presented the new *Forage Economics Calculator* to the members of the Stockmens' Association. It is highlighted on Page 11.

The Nature Conservancy Conservation Science Summit Dr. David Toledo presented a virtual poster *"Ecosystem change monitoring, climate change & human dimensions"* at The Nature Conservancy Conservation Science Summit. https://www.nature.org/en-us/about-us/where-we-work/united-states/stories-in-mn-nd-sd/conservation-science-summit/?tab_q=tab_container-tab_element_463