USDA Agricultural Research Service
Northern Great Plains Research Laboratory
February 2016

INTEGRATOR

www.ars.usda.gov/pa/ngprl

Ground beef as a useful source of omega-3 fatty acids?

Dr. Scott Kronberg

Cattle that have a fresh carcass weight over 600 pounds, a good size ribeye and enough intramuscular marbling fat to grade Choice or even Prime is the production goal of most feedlot finishing programs. This requires many months of high feed energy intake and this usually comes from grain or perhaps high quality forage such as immature perennial grasses in prime condition or annual grasses such as millet or corn.

However, it is much more difficult to sustain high feed energy intake month after month with only forages so supplementing forage intake with grain and (or) pulses and oilseeds is necessary if the goal is to fatten yearling cattle to choice grade while grazing summer and fall pastures in the northern Great Plains. This may interest producers who want to recycle nutrients in manure and urine directly back to pasture soils without the costs of using machinery for this, as well as avoiding most of the costs associated with feedlot production. Additionally, the quality of fat in beef can be altered depending on which concentrates are fed to grazing yearlings. Current research trials at the lab are designed to alter the fatty acid composition of beef from grazing yearlings to a greater extent than we and others have accomplished previously. The rationale behind this work is supported by new research from scientists who are focused on improving our understanding of links between human fat intake and nutrition and good health.

There is increasing evidence that DHA, the omega-3 fatty acid required for proper brain function, does not have to be obtained by consuming fish such as salmon but rather can be synthesized in people from the more common and abundant omega-3 fatty acid alpha-linolenic acid (ALA). This omega-3 fatty acid can be increased in beef and other livestock products by feeding livestock plant materials such as flaxseeds and green forage that contain ALA. Also, if we feed the cattle enough Vitamin E with the flaxseed, then we hope to prevent formation of chemicals in beef that are associated with undesirable flavors.

This is good news! If we are successful with current research to put more ALA into muscles of cattle and in particular the muscles used for ground beef, this would provide a relatively low cost source of ALA in a popular form of animal protein.

continued on page 2

In this issue:

Ground beef as a useful source of omega-3 fatty acids 1
Message from Matt 2
Grazing and Kentucky bluegrass effect on infiltration 3
Revisit the Crop Sequence Calculator 4
"Farming for the Bottom Line" conference 5
Success with late-seeded cover crops driven by timely precipitation 6
Update on Crop Species Diversity Changes in the United States 7
Soil's hard work 9
Are complex cover crop mixtures more resilient to drought? 10
New faces 12

Message from Matt

Welcome to 2016:

The scientists and staff here at the NGPRL hope your new year is off to a good start. We are looking forward to the coming year and to capitalizing on our progress in 2015 by taking our innovative research program to a new level.

To recap, in 2015 we were very pleased to bring on several new hires as scientists, post docs, technicians, and administrative staff. Most recently, we hired David Toledo as a new permanent full-time scientist. David previously was a post doc here at the NGPRL. In his new position, David will focus on integrated crop-forage-livestock systems. Jennifer Carter was hired in November as a new Computational Biologist to manage the huge amounts of data we generate. Mark Liebig hired Justin Reeves as a post doc to help with an international effort on agricultural greenhouse gases. Krystal Leidholm was hired in October as a new Biological Technician to support Long-Term Agroecosystem Research (LTAR) Network research. In addition to new employees, we were also able to upgrade our broadband connection to improve our ability to handle large volumes of electronic data and we upgraded several pieces of field and lab equipment.

Looking ahead to the remainder of 2016, we plan to hire another new scientist, a field technician, and an office assistant. Completing these hires will bring us near our previous staffing levels of 2011. We will also implement new research on long-term cropping systems as part of the LTAR network.

Lastly, we hope you can attend our winter workshop on "Farming for the Bottom Line" on March 1 at the National Energy Center of Excellence on the Bismarck State College campus. Last year's inaugural event was very successful and we expect another well attended conference this year. And, we look forward to welcoming you to our annual Friends and Neighbors Day on July 28.

Dr. Matt Sanderson
Research Leader

Ground beef as a useful source of omega-3 fatty acids? *continued from page 1*

Relevant published scientific papers:

Kronberg, S.L., E.J. Scholljegerdes, A.N. Lepper, and E.P. Berg. 2011. The effect of flaxseed supplementation on growth, carcass characteristics, fatty acid profile, retail shelf life, and sensory characteristics of beef from steers finished on grasslands of the northern Great Plains. J. Anim. Sci. 89:2892-2903. https://www.animalsciencepublications.org/publications/jas/articles/89/9/2892

Kronberg, S.L., E.J. Scholljegerdes, E.J. Murphy, R.E. Ward, T.D. Maddock, and C.S. Schauer. 2012. Treatment of flaxseed to reduce biohydrogenation of α-linolenic acid by ruminal microbes in sheep and cattle and increase n-3 fatty acid concentrations in red meat. J. Anim. Sci. 90:4618-4624. https://www.animalsciencepublications.org/publications/jas/articles/90/12/4618

Scott Kronberg 701.667.3013 scott.kronberg@ars.usda.gov

Cattle grazing and Kentucky bluegrass invasion effects on water infiltration and runoff at the USDA-ARS Northern Great Plains Research Laboratory

Drs. David Toledo and Matt Sanderson

Despite evident changes in species composition and overall ecosystem function throughout the northern Great Plains, interpreting indicators of rangeland health assessments show little to no departure from reference condition.

These differences are in large part attributable to invasion of Kentucky bluegrass, smooth brome and other exotic grasses into what used to be prairie dominated by native plant species. According to National Resource Inventory data, Kentucky bluegrass is now present in over 85% of the areas sampled.

This non-native, perennial, cool season grass can serve to stabilize soils and increase site stability. It affects nutrient flows, soil structure, and plant community composition affecting biotic integrity. It affects the hydrologic function of an area by changing root structure and the way in which water flows, is captured and then safely released back into the ecosystem.

In 2014 we used a large rainfall simulator and two laboratory tests: (1) the water droplet infiltration time and (2) the molarity of ethanol droplet test.

Figure 1. Visual description of how cores were separated into strata.

Figure 2. David Toledo performing the molarity of ethanol droplet test of Kentucky bluegrass samples.

These experiments were used to determine whether the presence of a Kentucky bluegrass root mat, thatch, and litter layers (Fig. 1) affected water infiltration and therefore hydrologic function of these Kentucky bluegrass dominated ecosystems.

Additionally, we fenced off 3.5 acres and heavily grazed these to determine whether heavy grazing of Kentucky bluegrass dominated areas had an effect on water runoff and water infiltration time.

Our results show that there was no statistical difference in infiltration and runoff of grazed versus ungrazed moist Kentucky bluegrass dominated areas.

However, there is a positive relationship between the percentage of Kentucky bluegrass in the plant canopy and the amount of runoff discharge. As the percentage of Kentucky bluegrass increases, so does the amount of runoff discharge.

Hydrophobicity testing (Fig. 2) of cores taken at these locations also revealed that when dry, Kentucky bluegrass litter is significantly more hydrophobic than thatch, root mat or mineral soils at these same locations.

Although still preliminary, this research highlights the importance of management strategies that minimize excessive accumulation of Kentucky bluegrass litter.

This successful collaboration with the USDA-ARS Great Basin Rangelands Research unit in Reno, Nevada will lead to further work on rangeland soil erosion in North Dakota.

During each of the next three years, the team from Reno will be traveling to North Dakota for two weeks to conduct follow up research on rainfall simulation.

Matt Sanderson 701.667.3010 matt.sanderson@ars.usda.gov
David Toledo 701.667.3063 david.toledo@ars.usda.gov

Revisit the Crop Sequence Calculator

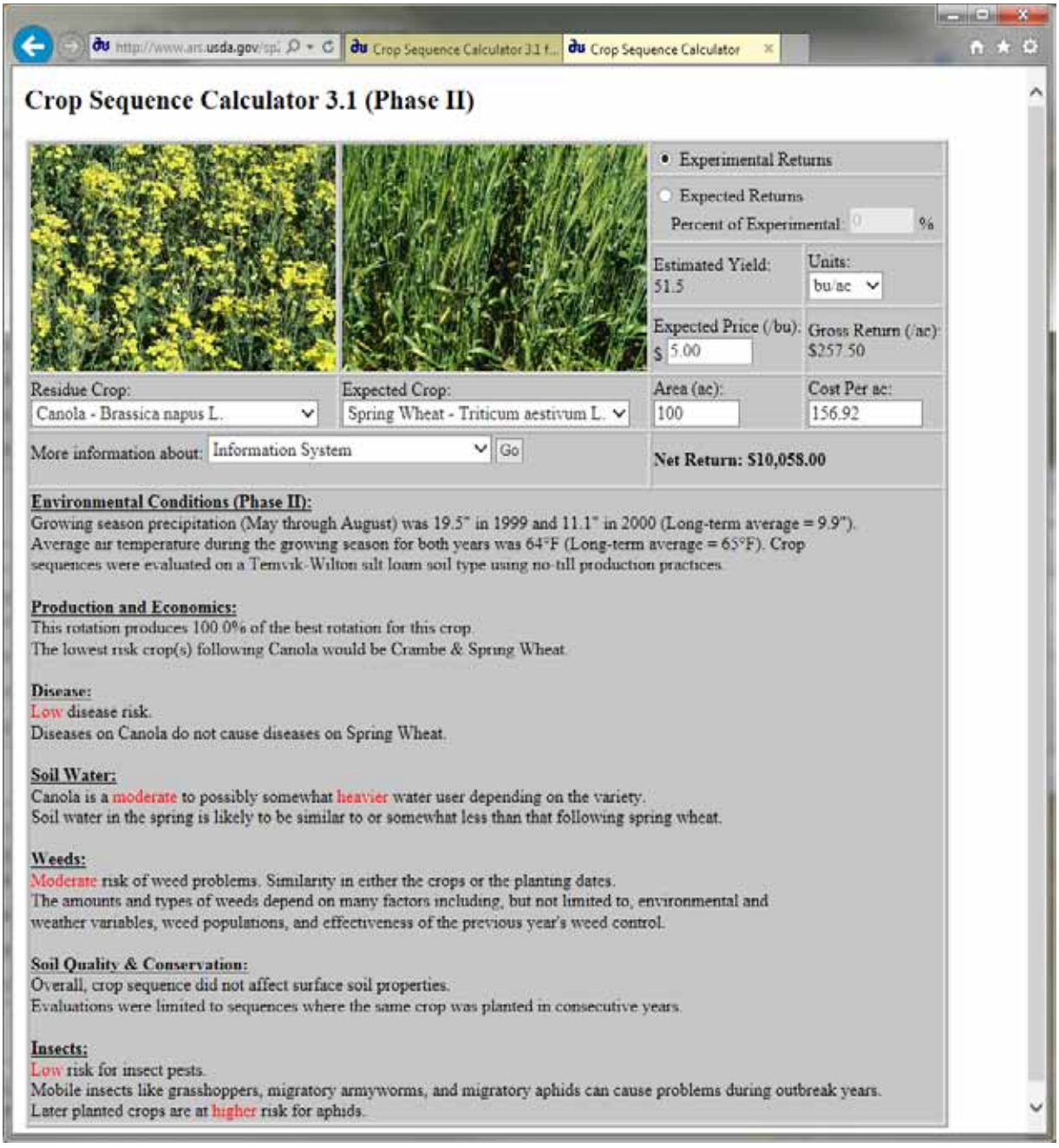
Dr. David Archer

Cropping decisions can be particularly important when economic conditions are challenging, and crop sequence can have a large effect on crop productivity and profitability. The Crop Sequence Calculator is a tool that was developed to help producers evaluate cropping options.

The calculator uses yield data collected at the Area 4 Farm growing 10 crops on 10 different crop residues over relatively wet years (1999, 2000) and relatively dry years (2003, 2004). The crops included Canola, Dry Pea, Spring Wheat, and Sunflower over both time periods with Barley, Crambe, Dry Bean, Flax, Safflower, and Soybean included in 1999-2000, and Buckwheat, Chickpea, Corn, Grain Sorghum, Lentil, and Proso Millet in 2003-2004.

Users can enter their own crop price and production information to evaluate crop sequence options for their own farm. The calculator has undergone several updates over time. It is available to download and install on your computer, or can be used interactively on the web. Both versions can be accessed from the following website: http://www.ars.usda.gov/services/software/software.htm?modecode=30-64-05-00, or just do a search for "Crop Sequence Calculator" using your favorite search engine.

David Archer 701.667.3048 david.archer@ars.usda.gov



Area 4 SCD Cooperative Research Farm
Bismarck State College Agriculture Department
NDSU Extension Service
North Dakota Agricultural Experiment Station
USDA-ARS Northern Great Plains Research Laboratory
USDA Natural Resources Conservation Service

FARMING FOR THE BOTTOM LINE

Tuesday, March 1, 2016 9:30 AM cst Registration

Bismarck State College, National Energy Center of Excellence, Bavendick State Room

1500 Edwards Ave, Bismarck ND

Online Registration!

Register now at: www.tinyurl.com/2016Farming

to join us for this FREE 1-Day seminar! 6 CCA CEUs available.

If you are unable to register online, please call the
NDSU Extension Service of Morton County at 701-667-3340.

MUST register *no later than* February 22, 2016

Registration, Coffee, Posters, Exhibitors

Will I Ever See Good Prices Again?..... Dr. Frayne Olson, NDSU Ag Economist

Lessons from the Area 4 SCD Cooperative Research Farm.....Dr. Dave Archer, USDA-ARS Ag Economist

Characteristics of Profitable North Dakota Farms.....Andy Swenson, NDSU Extension Economist

LUNCH PROVIDED

The Impact of Weather in North Dakota 2016 Farm Production.....Dr. Adnan Akyuz, North Dakota Climatologist

Delivering Knowledge from Improved Management.....Dr. Mark Liebig, USDA-ARS Research Soil Specialist
Dr. David Toledo, USDA-ARS Rangeland Management Specialist

Rural Community and Family Resilience.....Dr. Gary Goreham, NDSU Rural Sociologist

Farm Business Management Panel - Moderated by Al Gustin.....Roger Gussiaas, Carrington ND; Cody Sand, Forbes ND;
Mark Jennings, Washburn ND

Requests for accommodation related to disability and/or dietary needs should be made to NDSU Extension/Morton County at 701-667-3340 by February 22, 2016.

Use of product or corporation names or trademarks does not constitute official endorsement by sponsors. The sponsors prohibits discrimination in all programs and activities based on race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital and family status.

Success with late-seeded cover crops driven by timely precipitation

Dr. Mark Liebig

Cover crops can play an important role in cropping systems by providing valuable agronomic and environmental services.

Using cover crops to extend the traditional growing season through inter- and/or double-cropping allows livestock producers to increase forage availability, often at a time of the year when abundant, quality forage from grassland has declined.

Cover crops grown for forage also offer the potential to enhance desirable agroecosystem co-benefits, including improved nutrient-use efficiency and soil tilth, reduced pests, and increased yield and yield-stability.

Realizing such benefits over the long-term can translate to cropping systems with increased resilience and lower environmental impact, thereby creating a more sustainable agriculture.

Sound management guidelines for the use of cover crops in semiarid cropping systems is currently constrained by a lack of information. To address this need, researchers from the USDA-ARS Northern Great Plains Research Laboratory quantified agroecosystem responses to late-summer seeded cover crops under no-till management, with particular emphasis on soil properties.

The study was conducted from 2008-2011 on the Area IV Soil Conservation Districts Research Farm near Mandan, North Dakota.

Above ground cover crop biomass was highly variable throughout the study (86-1276 lb/ac/yr), and was strongly affected by precipitation received within two weeks of cover crop seeding.

Late-summer seeded cover crops were effective in reducing the amount of available soil nitrogen in the spring, particularly during 2009 and 2011 when biomass production the preceding year was abundant.

Cover crops did not induce soil water deficiencies for cash crops in the following spring, nor did they affect near-surface soil properties or soil coverage by residue.

Findings from the study suggested late-summer seeded cover crops can provide quality forage for livestock in the fall and conserve soil nitrogen in the spring, but achieving such outcomes consistently depends on timely precipitation after cover crop seeding.

Full study results can be found in the November-December 2015 issue of *Agronomy Journal*.
Mark A. Liebig, Research Soil Scientist
Adapted from Liebig, M.A., J.R. Hendrickson, D.W. Archer, M.A. Schmer, K.A. Nichols, and D.L. Tanaka. 2015. Short-term soil responses to late-seeded cover crops in a semi-arid environment. Agron. J. 107(6):2011-2019.

View the full article online at
https://dl.sciencesocieties.org/publications/aj/abstracts/107/6/2011

Mark Liebig 701.667.3079 mark.liebig@ars.usda.gov

Production from late-summer seeded cover crops can vary considerably.

Update on crop species diversity changes in the United States: 1978-2012

Drs. John Hendrickson, David Archer, and Mark Liebig.

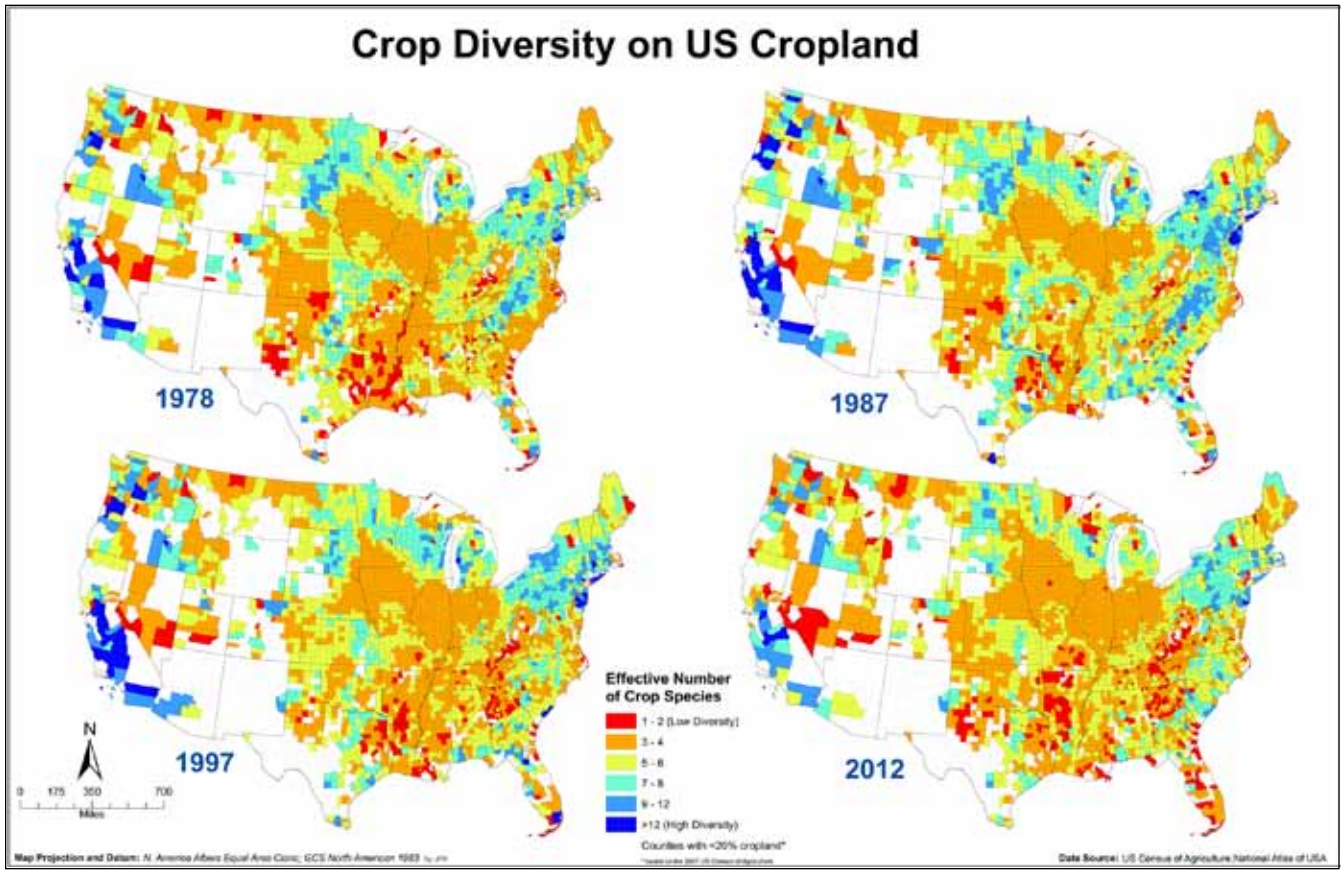


Figure 1. Crop species diversity for each county in the continental United States in 1978, 1987, 1997 and 2012. The redder hues indicate less crop diversity while the bluer hues indicate more crop diversity within each county.

Ecologists generally feel that diversity is one of the most important components in ensuring a healthy ecosystem.

In cropping systems, diversity is also important for processes such as nutrient cycling, water use, pest and disease control and weather variation.

In the February 2012 issue of the Integrator (http://www.ars.usda.gov/SP2UserFiles/Place/30640500/Newsletter/Feb2012.pdf), we reported on initial analysis of changes in diversity in the United States between 1978 and 2007, using National Agricultural Statistics Service (NASS) 'Census of Agriculture' data.

Because the Census of Agriculture is conducted every 5 years, the availability of the 2012 data in May, 2014 allowed us to include the relatively high crop prices that occurred after 2007.

The Census of Agriculture provides two key pieces of information needed to evaluate crop diversity: the number of crops within each county and the acreage for each crop. By using this information, we could develop a diversity index for each county that adjusted for number of crops and how evenly these crops were distributed. This is important since using the number of crops without adjusting for distribution can provide a biased picture of crop diversity.

Two trends from this data are revealed by looking at Figure 1. First, crop diversity at the national level decreased over time and second, this decrease was not evident in all areas of the country. For example, central North Dakota was less diverse in 1978 than in 2012 while the opposite trend can be seen in southeast North Dakota and central Minnesota.

We looked at dominant crops within each county using Ag Census data from North Dakota for potential explanation of these trends. Figure 2 shows changes in crop diversity for each Census of Agriculture for North Dakota.

We also looked at the most dominant crop within each county for each census period. In 1978, small grain dominated most of the state; however, by 2002 soybeans dominated cropland in the south east portion of the state. By 2012, soybeans were dominant in the eastern half of North Dakota.

continued on page 8

Update on Crop Species Diversity Changes in the United States: 1978-2012 *continued from page 7*

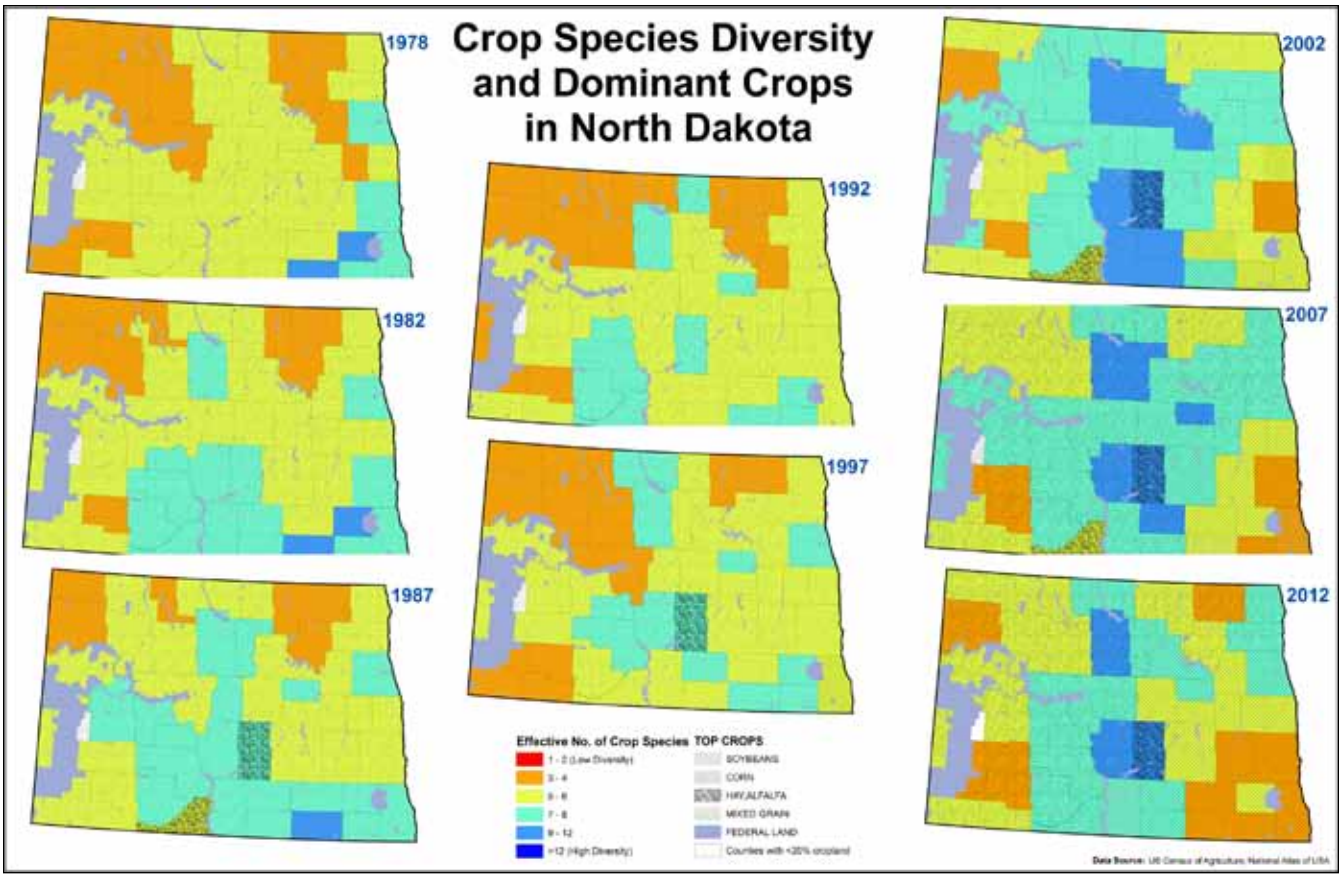


Figure 2. Crop diversity and dominant crops for each county in North Dakota in 1978, 1982, 1987, 1992, 1997, 2002, 2007 and 2012. The redder hues indicate less crop diversity while the bluer hues indicate more crop diversity within each county. Counties are also shaded to represent different dominate crops at each census point.

Crop diversity in south east North Dakota also started to decline during this time frame.

While the increase in soybean production did occur with declines in crop diversity, it is important to realize that there were multiple factors that may have affected crop diversity in North Dakota during this time frame.

No-till helped to conserve soil water which allowed producers to increase cropping intensity and grow more crops.

The fusarium head blight affected small grain production and many producers looked for alternative crops.

Also, improved genetics and technology and rising crop prices have made corn and soybean both more attractive to producers and easier to grow throughout North Dakota.

Prior to this paper there had been a lot of discussion about changes in crop diversity in the United States but very little hard data.

Understanding crop diversity was important since croplands are 22% of the total land base in the lower 48 states. This paper provided the first evaluation of national crop diversity over a relatively long time frame.

Questions still remain on why crop diversity has increased in some regions and decreased in others. Answering these questions is critical for understanding factors that contribute to enhanced crop diversity in our agro-ecosystems.

Adapted from 'Crop Species Diversity Changes in the United States: 1978-2012'. J. Aguilar; G.G. Gramig, J.R. Hendrickson, D.W. Archer, F. Forcella, M.A. Liebig. PLOS One 10(8) 2015. This article is available online at (http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0136580)

John Hendrickson701.667.3015 john.hendrickson@ars.usda.gov
Mark Liebig 701.667.3079 mark.liebig@ars.usda.gov
David Archer 701.667.3048 david.archer@ars.usda.gov

Soil's hard work

by Raylene Nickel, Successful Farming Magazine

Researcher Mark Liebig describes soil as earth's "biogeochemical regulator." Soil's important work earns the term.

In sum, soil has the potential to cycle nutrients from plants, regulate and filter water, and build carbon by sequestering it from the atmosphere. Operating hand-in hand, these workmanlike processes have a hidden, yet significant, outcome.

"Soil provides an array of services," says Liebig, a soil scientist at the USDA-ARS Northern Great Plains Research Laboratory (NGPRL), Mandan, North Dakota. "Of paramount importance is the soil's ability to regulate atmospheric quality," he says. "Indirectly, land management plays a critical role in facilitating this regulation of the atmosphere. Thus, management of the land influences soil's ability to serve as a sponge for carbon dioxide."

The management practices most likely to help soil in its most important work are reported in the results of a recently completed NGPRL study.

"Of the broad array of management decisions under direct producer control, crop rotation perhaps represents the most significant in terms of its effect on long-term economic and environmental outcomes," says Liebig. "There has been increasing emphasis placed on developing agricultural production systems that are inherently resilient to external stressors yet are highly productive, economically competitive, and environmentally benign."

In the context of environmental outcomes related to soil ecosystem services, the effects of crop rotation are most evident in altered soil structure, soil water properties, or nutrient retention and availability.

THE ROTATIONS

The NGPRL study evaluated the effects on near-surface soil conditions of four no-till cropping systems in central North Dakota.

The field-scale comparisons included:

- **A small-grain/fallow system started in 1984.** Crops grown in this treatment included spring wheat, barley, or oats.
- **A three-year rotation also started in 1984.** Crops included spring wheat, winter wheat, and sunflower.
- **A five-year rotation started In 2001.** Crops produced were spring wheat, winter wheat, dry peas, corn, and soybeans.
- **A dynamic rotation including six of the following crops:** corn, sunflower, spring wheat, winter wheat, soybeans, and buckwheat. "Crops in the dynamic rotation were sequenced each year based on market opportunities, soil water and nutrient conditions at planting, or restrictions on herbicide use within the planted field," says Liebig.
- **A moderately grazed pasture that had never been tilled.** This served as a baseline comparison for the crop rotations.

"The study showed that diversity of rotation has a pronounced effect on the physical condition of the soil, its chemistry, and the amount of organic matter in the soil," says Liebig. "Soil organic carbon and total nitrogen were greater in the five-year and dynamic rotations compared with the three year and small-grain/fallow rotations." All assessments for soil quality were highest in the grazed pasture.

"The overall findings suggest increasing soil organic matter in northern Plains no till cropping systems requires not just continuous cropping, but a diverse mixture of crops sequenced in a manner to enhance biomass production over the long term," he says. "Crops included in the five-year and dynamic rotations were sequenced to favor snow capture and efficient precipitation and nutrient use, which enhances production over a rotation cycle."

continued on page 10

Soil's hard work *continued from page 9*

Multiple factors are at play in a sequencing pattern that capitalizes on synergism between crops. A synergistic sequencing that had the effect of increasing crop residue was the planting of corn after dry peas in the five-year rotation.

"Sequencing corn after dry peas was found to increase the production of corn residue by 33% to 55% compared with planting corn after corn," says Liebig.

"Conversely, sunflower, a crop well known for high water use and limited residue production relative to other crops common to the northern Plains, can severely restrict crop production in subsequent years when precipitation is below average. Given the inclusion of sunflower in the three-year rotation and coupled with the consistency of periodic drought in the region, reduced production of spring wheat would be expected during drought years following sunflower." The decreased wheat yield would, of course, reduce crop residue.

Besides increasing soil organic carbon, crop diversity also improved bulk density in the soil. A low numerical measurement of bulk density indicates soil with open pore spaces. These allow the translocation of air, water, and nutrients. Soils with high soil bulk density indicate a tightly structured soil that restricts root growth. The five-year rotation had the lowest soil bulk density, while the grazed pasture was lowest of all.

Bulk density of the soil affects water infiltration. "There was a notable numerical trend among treatments, with infiltration rate increasing with rotational diversity," says Liebig.

"The results clearly show that crop diversity plays a role in inducing the kinds of changes in soil properties that we know are needed for the development of a more sustainable agriculture," he says.

"This addresses the whole evolution of cropping systems and suggests the need to look beyond the concept of no-till," he says. "Simply switching to no-till is not enough to realize soil-health benefits over the long-term. In addition to no-till, we should also consider the rotational benefits to be found in the broad portfolio of crops that are adapted to any given region."

Mark Liebig 701.667.3079 mark.liebig@ars.usda.gov

Are complex cover crop mixtures more resilient to drought?

Dr. Jose Franco

Multi-species cover crop cocktails are recommended to producers as a way of providing soil coverage during fallow periods and maximizing benefits to the ecosystem.

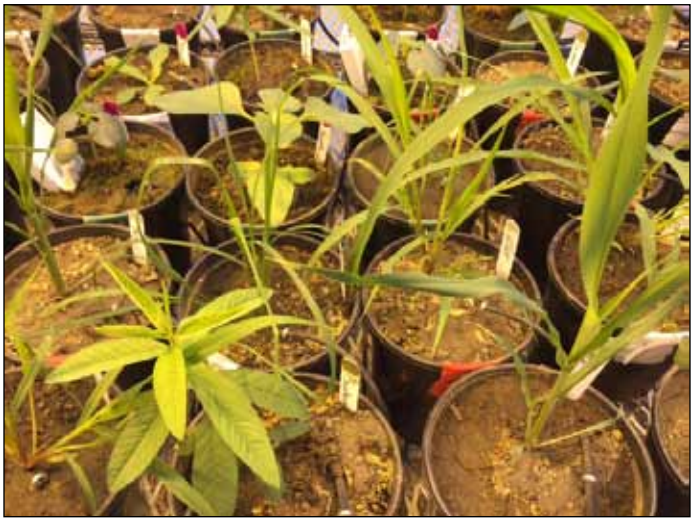
Some often-cited benefits include enhanced nutrient availability for the cash crop in the spring, reduced soil erosion, reduced nutrient losses due to runoff and/or belowground leaching, improved pollinator and wildlife forage and habitat, and enhanced livestock forage in integrated systems.

However, costs associated with cover crop cocktails can be high and little is known about the establishment success of individual species in these mixtures, which can sometimes contain up to 16 or more species depending upon the mixture and goals of the producer.

Additionally, changes in precipitation patterns in the semi-arid Northern Great Plains in recent decades indicate earlier and wetter springs and climate change models predict fewer but larger rainfall events, further adding to the uncertainty of establishment and species success in mixtures.

Given the unpredictability in climate patterns, it is important to have a better understanding of individual cover crop species performance and interactions with other species under altered moisture conditions. This will help us in identifying species and combinations that are robust and perform well under variable precipitation so that producers can select the most cost-effective mixtures that will maximize the intended benefits.

Currently, there is primarily anecdotal evidence that cover crop mixtures are more resilient to drought and extreme precipitation patterns as compared to single species stands.



At the NGPRL, we are conducting a multiple phase study to examine species establishment in complex mixtures and to determine whether or not complex cover crop mixtures perform better under drought conditions in this region.

The study consists of a screening phase whereby a total of 29 cool and warm

continued on page 12

Are complex cover crop mixtures more resilient to drought? *continued from page 11*

season cover crop species are being tested for drought tolerance in a greenhouse setting.

The ultimate goal is to identify species that exhibit resilience to extremes and include them in multi-species mixtures in a second greenhouse phase and finally in the field portion of the study where they will be tested under natural climate conditions.

We anticipate that the results from this research will serve as an additional tool in aiding producers to make informed decisions on cover crop species and mixture selections so that they may maximize profit and optimize the benefits gained from cover crops.

If cover crop mixtures are more resilient to drought, what are some of the mechanisms by which this may be possible?

Interactions between different species in cover crop mixtures will affect the establishment, as well as growth rates, of individual species. Species interactions may drive competition for light, water, and nutrients. Belowground competition for water and nutrients may potentially lead to more root production as well as deeper roots in search of untapped resources.

A plant with a more prolific and deeper root system may have more access to deeper water sources and, thus, an advantage during times of drought.

There may also be some positive interactions between species, whereby one or more species benefit from having other species nearby. This phenomenon is thought to be enhanced during times of stress, such as would occur in drought conditions.

Additionally, complex plant canopies created by multi-species mixtures may alter the microclimate just above the soil and reduce evaporative losses, thereby reducing water and heat stress.

In summary, there are a complex set of interactions that may enable multi-species mixtures to survive and even thrive during times of drought. However, these are all conjectures based on ecological theory. With our current research, we hope to answer the question “Are complex cover crop mixtures more resilient to drought?” and, if so, provide some insight as to the mechanisms behind this phenomenon.

Jose Franco 701.667.3008 jose.franco@ars.usda.gov

New faces

Jennifer Carter has joined the NGPRL as a Computational Biologist. Jennifer is originally from North Carolina, but has lived in Montana and South Dakota since 1994. She previously served the North Dakota National Guard as the GIS Coordinator for Engineering and Facilities. Prior to being with the National Guard, Jennifer served nine years with Department of Homeland Security, Federal Emergency Management Agency, as a GIS Lead working nationwide on Presidentially Declared Disasters. She received her Bachelors in Biology from North Carolina State University.

Jennifer Carter

Dr. David Toledo has joined the staff of the Northern Great Plains Research Laboratory as a Research Rangelands Management Specialist. He has been a Post-Doctoral Research Associate at the lab since 2013. His research focuses on ecosystem health evaluation and finding ways of optimizing land management practices under changing climate and land-use scenarios. Dr. Toledo received his Ph.D. from Texas A&M University.

David Toledo

Krystal Leidholm has joined the NGPRL staff as Biological Science Technician. She has been supporting the “Renewal of the Standing Rock Sioux Reservation: Land, Cattle, Beef, and People” project in a term employee position. Leidholm, a native of Washburn, ND has a Master’s degree in Environmental Sciences: Conservation Biology from Green Mountain College in Vermont. Prior to her initial position at NGPRL, she was at the North Dakota Department of Parks and Recreation.

Krystal Leidholm