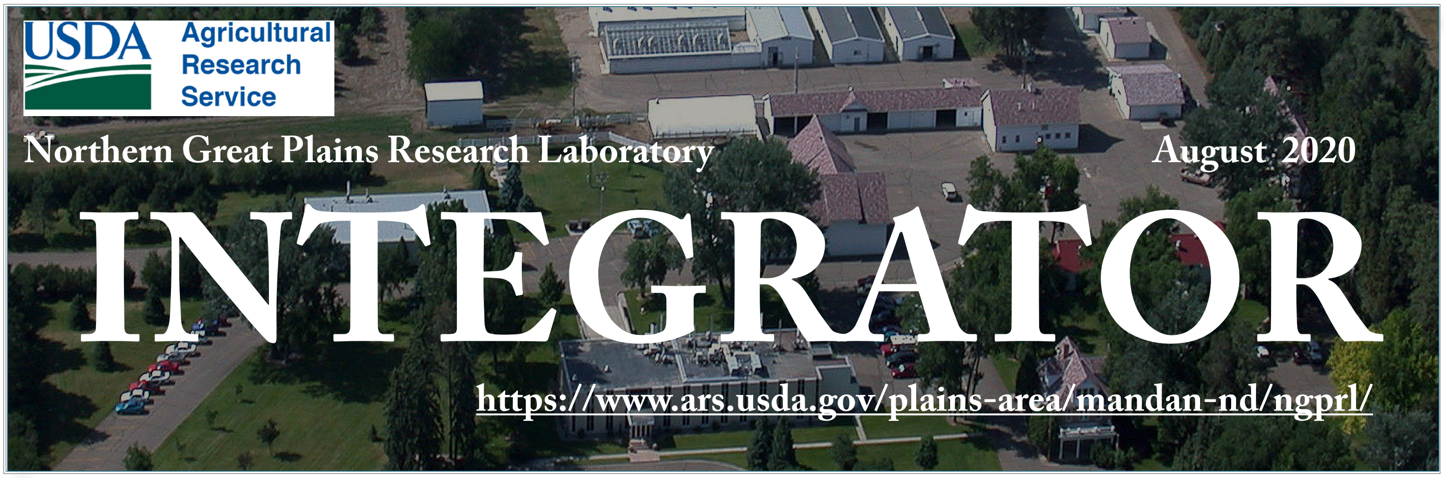

Perennial Forages Influence Mineral Quality in Annual Cropping Systems

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

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


Image 1. Plots showing field study

In This Issue:

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

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

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

Grain weight (TKW) was also different between years of harvest (Table 1; Image 2), and as grain weight increased, protein concentration and grain mineral

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

concentrations for zinc, potassium, magnesium, phosphorous, and sulfur decreased (Table 1).

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

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

Take home message

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

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

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

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

Mineral and Protein Relationships to Wheat Yield.

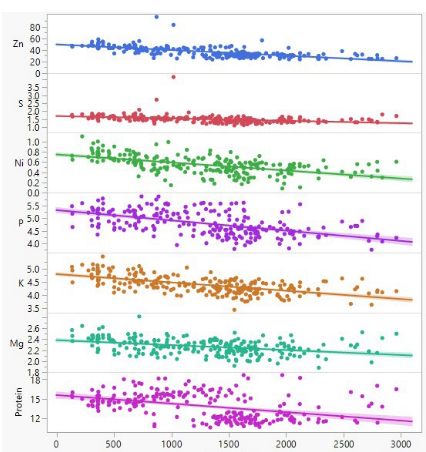

Figure 1. With increasing wheat yield (in kg / hectare), protein (%) and mineral concentrations zinc (Zn) and nickel (Ni), in micrograms / gram dry weight, and sulfur (S), phosphorous (P), potassium (K), and magnesium (Mg), in milligrams / gram dry weight, decrease. Data shown combines all four years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

Growing Season Precipitation

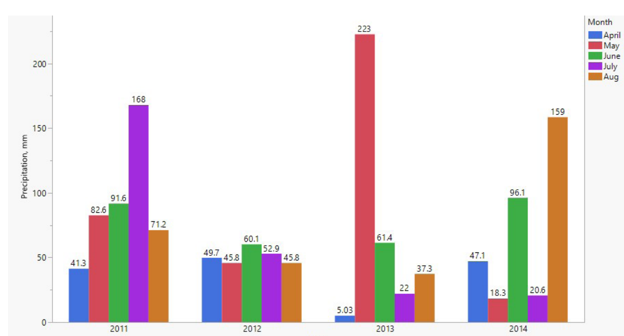

Figure 2. Monthly precipitation totals, in millimeters (mm), from April through August over four years (2011-2014).

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Message from Dave

Dr. David Archer, Research Leader

It is always important to remember that in agriculture we are producing food. In much of our research we look at ways to improve sustainability of agricultural production, producing more bushels of grain or pounds of beef while also providing benefits to soil resources and other ecosystem services, and doing it in a way that is economically viable for the producer. Increasing production is important since it means we are able to produce more food to keep people fed. But, a question we don't often ask is whether we are producing "better" food. There are a lot of ways we can think about food being "better". This can mean having higher quality, better flavor, or having higher nutrient concentrations or health benefits.

Most wheat producers are familiar with quality measures including protein content, test weight, falling number, and DON (vomitoxin) levels as these all affect the price received for the crop or determine whether it can even be sold. Similarly, beef producers may be familiar with quality measures like carcass quality grades. But, there are many characteristics that we don't routinely measure, which we do not consider in effects to our food supply, and are not rewarded in the market place.

We also know that there are many things we can do that affect the quality of the food we produce. We can select crop varieties or livestock breeds that tend to have higher quality characteristics. We can add inputs that increase nutrient content or protect against damage from pests or diseases. We can also select practices including tillage, rotations, cover crops, and grazing practices that have both short-term and long-term effects on soils and the biological, chemical, and physical growing conditions that affect grain, forage, and meat quality. However, the impacts of these practices on food quality are not as well known. New research is being initiated at the NGPRL (Mandan, ND), in collaboration with Grand Forks Human Nutrition Research Center (Grand Forks, ND) and the Edward T. Schafer Agricultural Research Center (Fargo, ND), to focus on better understanding how these practices influence the quality of the crops, forage, and livestock we produce and resulting impacts to food quality and ultimately human health. We hired Andrea Clemensen as a post-doctoral scientist to begin some of this research, and plan to hire a new scientist to expand this work. Some initial results are presented in this issue (p. 1). We look forward to sharing more as this research progresses.

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Prescribed Fire Perceptions and Potential Management Alternatives to Prescribed Fire

Dr. David Toledo

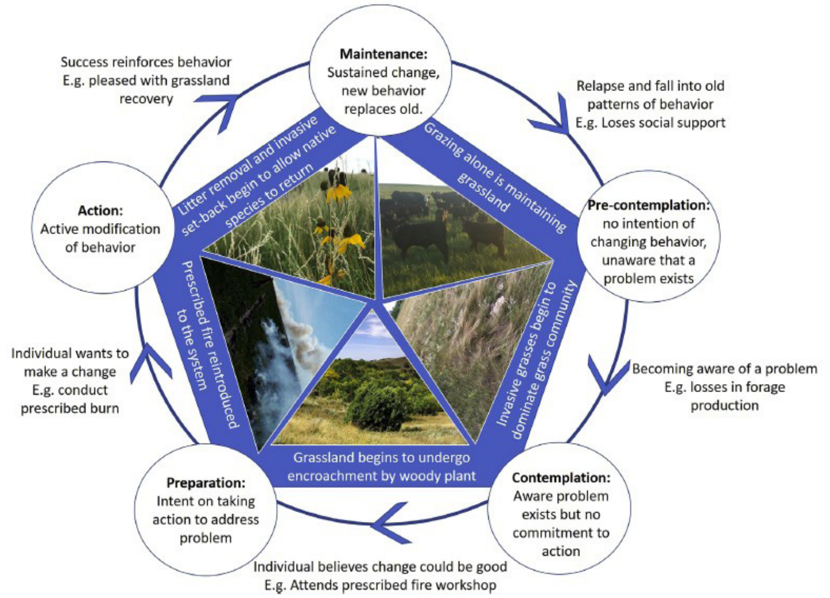

Figure. Model depicting stages of behavioral change in relation to current understanding of grassland succession and the role of prescribed fire. The model is useful for making inferences about landowner attitudes and behavior and for forming strategies to stimulate behavioral change that will result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

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

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

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

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

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Global Analysis Highlights Perennial Crop Effects on Soil Carbon

Dr. Mark Liebig

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

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

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

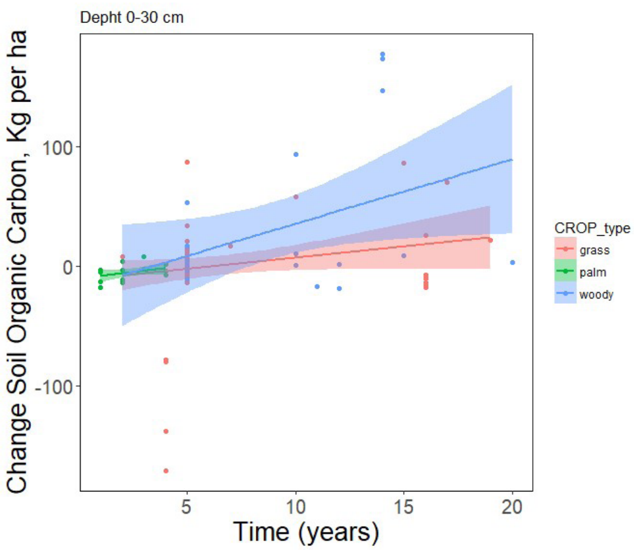
Perennial crops in the study were defined as crops that are planted, but not replanted and/or fully harvested annually to obtain goods. Perennial crops were categorized into two main groups: woody plants, such as fruits and nut crops (e.g., apple trees, citrus, almond), beverage crops (e.g., coffee,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

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

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

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

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



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

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

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

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

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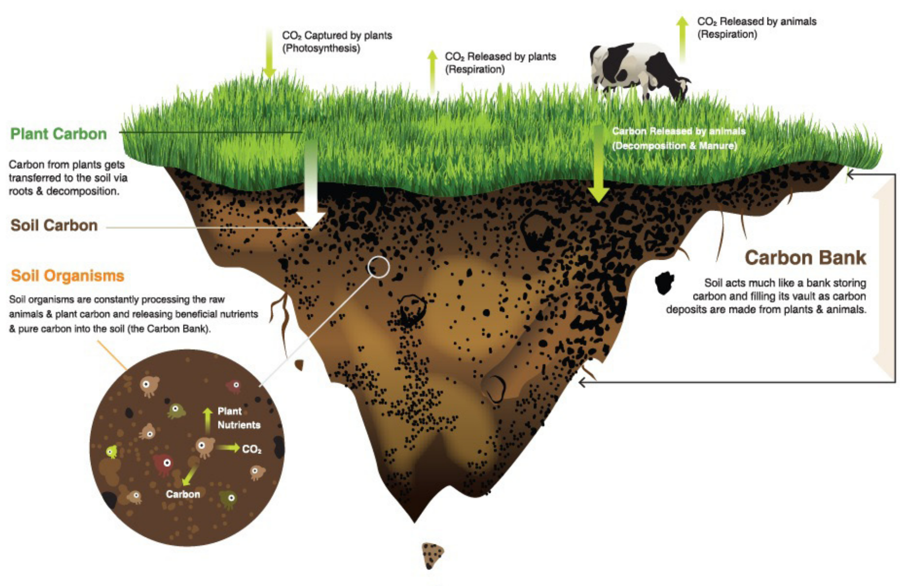

Managing carbon is key to soil health.
(*From http://australiansoil.com.au/soil-management-bebefits/*)

Fuel Consumption Comparison in Logistics of Aggregation of Biomass Bales - Tractor vs. Automatic Bale Pickers

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

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

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

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

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

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

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

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

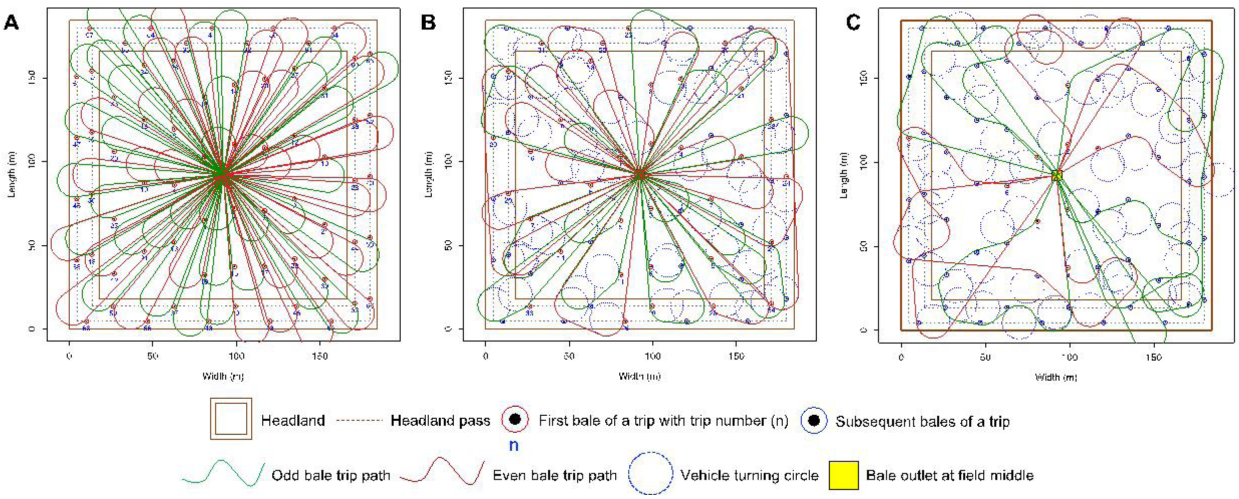

Figure 2. Bale aggregation equipment path simulation results: (A) Tractor, BPT (bales/trip) = 1; (B) Tractor, BPT = 2; and (C) Automatic bale picker, BPT = 8; Simulation data: area = 4 ha; turning radius = 10 m; biomass yield = 10 Mg/ha; bale mass = 500 kg; harvester swath = 9 m; field aspect ratio =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

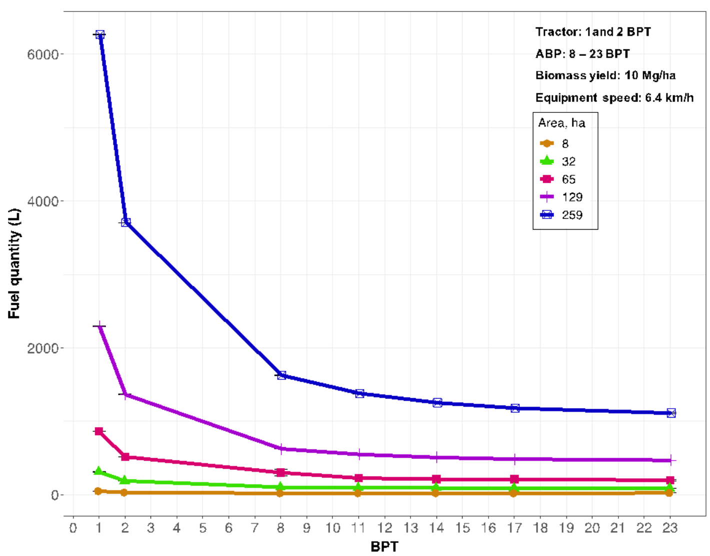

Figure 3. Effect of BPT (bales/trip) on the fuel quantity required by tractor and ABP (automatic bale picker) for aggregating 1–23 BPT for selected field areas of 8, 32, 65, 129, and 259 ha with 10 Mg/ha biomass yield.

Specific fuel quantity models with very good fit ($R^2 > 0.99$) were developed for tractor and ABP with the field area, biomass yield, and equipment speed as variables:

$$\text{Tractor (1 bale)}: Q_{\mathrm{F}} = 0.458 \times A_{\mathrm{F}}{}^{1.527}\, Y_{\mathrm{B}}{}^{1.345}\, S_{\mathrm{P}}{}^{-0.999}$$
$$\text{Tractor (2 bales)}: Q_{\mathrm{F}} = 0.280 \times A_{\mathrm{F}}{}^{1.523}\, Y_{\mathrm{B}}{}^{1.338}\, S_{\mathrm{P}}{}^{-0.999}$$
$$\text{ABP (8 bales)}: Q_{\mathrm{F}} = 0.340 \times A_{\mathrm{F}}{}^{1.435}\, Y_{\mathrm{B}}{}^{1.179}\, S_{\mathrm{P}}{}^{-1.000}$$
$$\text{ABP (23 bales)}: Q_{\mathrm{F}} = 0.506 \times A_{\mathrm{F}}{}^{1.313}\, Y_{\mathrm{B}}{}^{1.135}\, S_{\mathrm{P}}{}^{-0.997}$$

where, QF is the fuel quantity utilized in bale aggregation (L); AF = field area (ha); YB = biomass yield (Mg/ha); and SP = equipment speed (km/h).

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

$$\text{Tractor (1 to 2 bales)}: \quad Q_{\mathrm{F}}\left[\frac{A_{\mathrm{F}} Y_{\mathrm{B}}}{-1.155 + 2.548 B_{\mathrm{T}} + 0.544 S_{\mathrm{P}}}\right]^{1.414} \quad (R^2 = 0.98)$$
$$\text{ABP (8 to 23 bales)}: \quad Q_{\mathrm{F}}\left[\frac{A_{\mathrm{F}} Y_{\mathrm{B}}}{-0.782 + 0.184 B_{\mathrm{T}} + 0.759 S_{\mathrm{P}}}\right]^{1.243} \quad (R^2 = 0.98)$$

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

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Plant Stand Spatial Distribution Analysis from UAS imagery using ImageJ Plugin and Uniformity Index

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Drs. David Archer, John Hendrickson, Jonathan Halvorson, and David Toledo, NGPRL, USDA-ARS

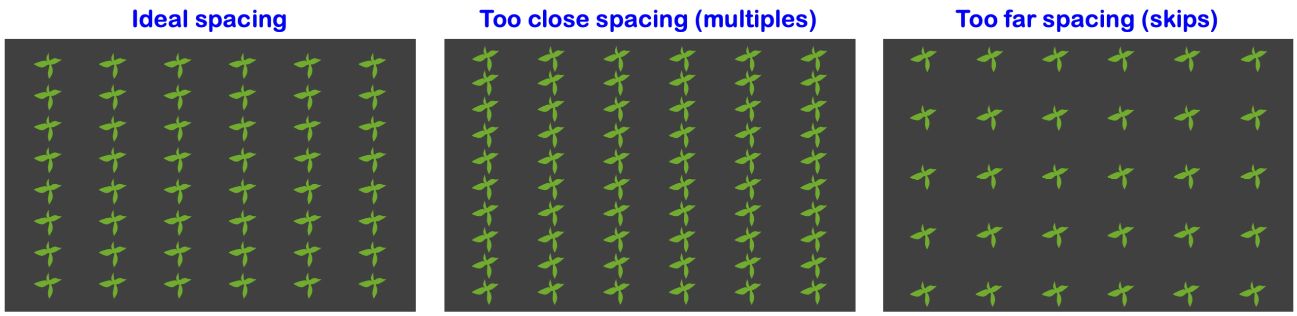

Figure 1. Simulated plants arrangement showing three different scenarios to demonstrate the lacuna of the existing spatial distribution measure such as standard deviation (SD). All these scenarios produce zero SD even though they deviated from the desired ideal plant spacing.

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

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

Another issue is that the manual distance measurements are performed only for a small portion at a few locations of the field, which might not sufficiently represent the overall spacing distribution. Nowadays, unmanned aerial system (UAS) images are increasingly being used in agriculture to obtain plant emergence status, stand count, growth characteristics, and crop health on a field scale.

Therefore, we used UAS images collected at the crop emergence stage and developed an image processing pipeline to analyze the whole field's crop spatial distribution. We further developed a novel spatial uniformity index that represents the distribution with respect to the ideal plant spacing.

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

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

We developed a new uniformity index that allows for assessment of the spatial distribution compared to the desired spacing, called the "ideal spacing uniformity index" (ISU) (equation in Figure 2). If all the seeds are perfectly placed at the ideal spacing, the ISUI will result in 100 %, while any deviation from the

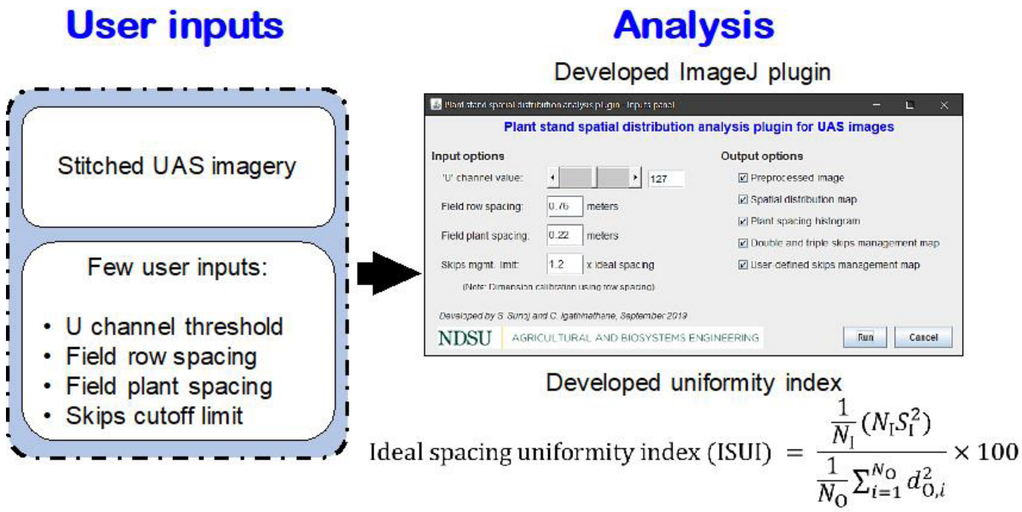

Figure 2. Plant stand spatial distribution analysis user inputs, the front panel of the developed ImageJ plugin, and ideal spacing uniformity index equation

ideal spacing will be penalized and result in a lower ISUI value, which is the desired and expected from a spatial distribution index. The performance of ISUI was compared with five other uniformity indices and was superior compared to others.

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

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

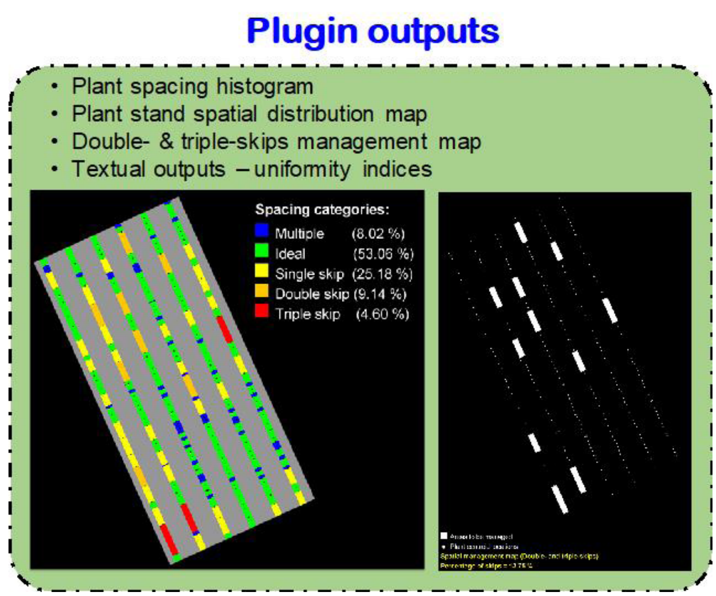

Figure 3. Plant stand spatial distribution analysis plugin output maps.

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Spinach Response to Salinity: Nutritional Value, Physiological Parameters, Antioxidant Capacity, and Gene Expression

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

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

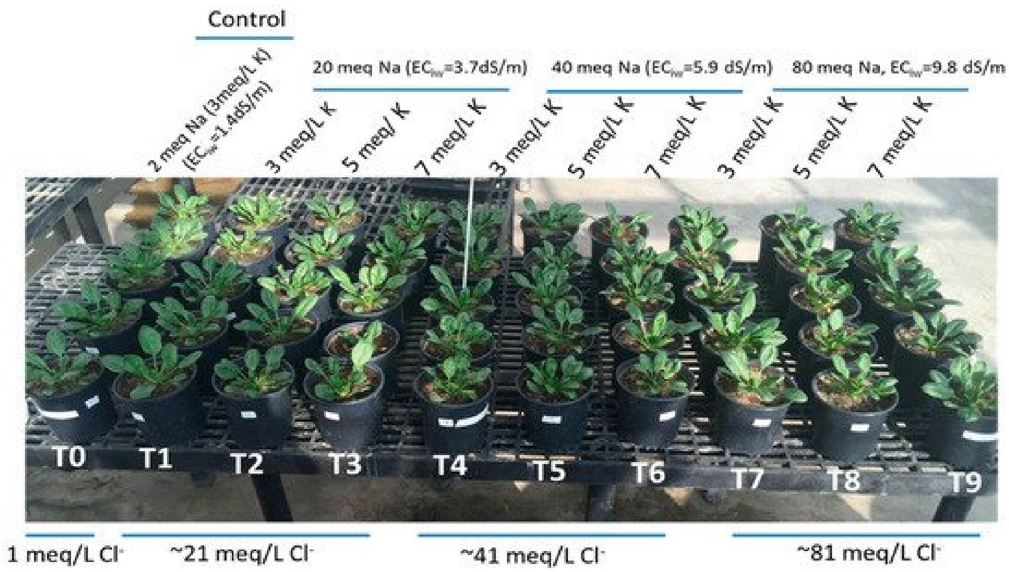

Figure 1. Spinach plants of the cultivar Raccoon 23 days after exposure to irrigation water salinities with electrical conductivities (ECiw) ranging from 1.4 dS m^{-1} (2 meq L^{-1} NaCl) to 9.8 dS m^{-1} (80 meq L^{-1} NaCl). NO_3^- and SO^{-2} were kept constant at 7.5 and 2.0 meq L^{-1}, respectively,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

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

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

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

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

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

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Data Security and Privacy in Precision Agriculture - Is Open Source Software a Possible Solution?

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

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

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

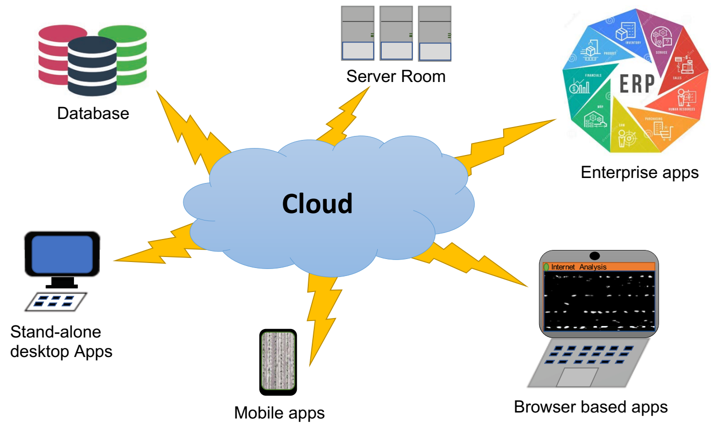

Figure 1. Components of cloud computing (Source of some imagies: google images).

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

A cost-effective approach to address this issue is to develop tools using "open-source" software. The term "open" means that the tool is available free of cost to view and use, while the "source" refers to the main computer program (source codes) that makes the software. At present - open source projects, products, or initiatives embrace and celebrate principles of open exchange, collaborative participation, rapid prototyping, transparency, meritocracy, and community-oriented development. Some of the advantages of using open source software are (i) no cost involved in software and their updates, (ii) latest developments are made readily

*Purdue Center for Commercial Agriculture, Producer Survey, April 2019 available, (iii) a huge community of developers and users contribute to the software, (iv) several well-tested routines/module have been developed and available for use, (v) the user-developed software can be readily shared and others can use them anywhere in the world, and (vi) it promotes data control and security. Along with the developed tool, the users own the data and do their analysis "on-demand" rather than upload their data, go through the waiting time, and get them analyzed by others. With this approach, the user retains control and responsibility for maintaining security of their data through regular back-up. One advantage of the paid cloud storage is that it is typically automatically backed up.

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

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

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

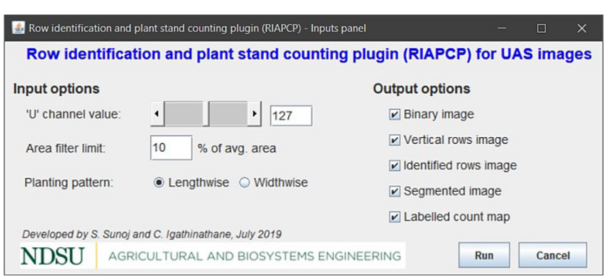

Figure 2. The front panel of the developed row identification and plant stand counting ImageJ plugin (RIAPCP).

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

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

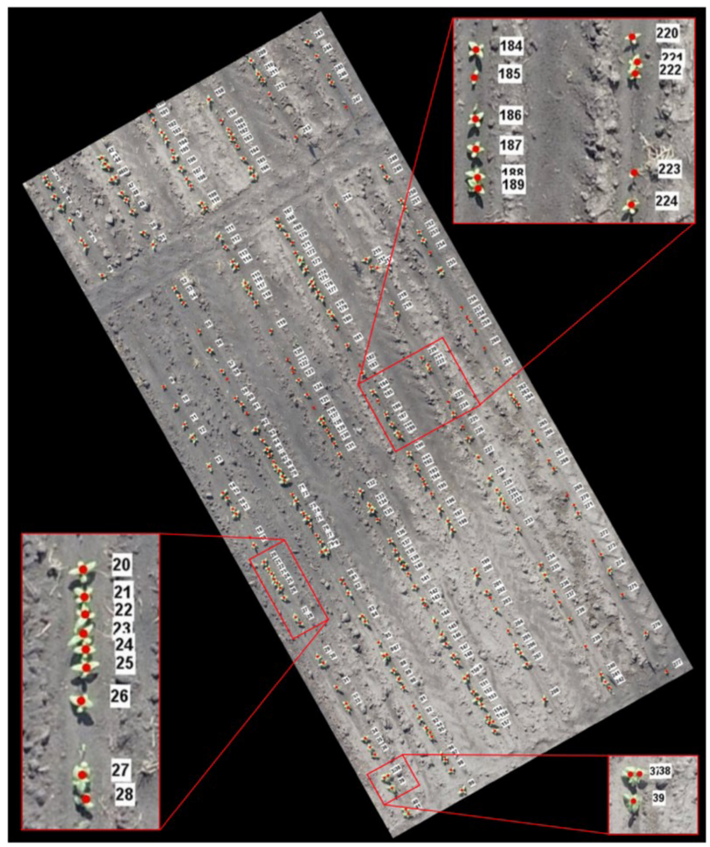

Figure 3. Plant stand count sequentially labeled along the rows from top to bottom and from left to right (Insets: zoomed portions to show the plants, markers, and labels clearly).

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Made from Plants?

Dr. Scott Kronberg

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

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

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

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

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

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

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

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

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

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

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

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Producers Can Watch Crop Develop Through ARS Cameras

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Interseeding study

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

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

Soil cover is "important" to the study.

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

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

Planting with no-till interseeder

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

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

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

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

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

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

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

Cover crop biomass, corn yields

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

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

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

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

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

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

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

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

Commodity crop: Sunflower

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

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

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

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

Would the study encourage more producers to grow more sunflowers?

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

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

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

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Exploring the Cultural Language of Soil: North American Soil Proverbs

Dr. Mark Liebig

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

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

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

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

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New Faces

Harsh Pathak

Harsh Pathak is a Masters student in the Department of Agricultural and Biosystems Engineering, NDSU. Dr. Igathinathane Cannayen is his major advisor and Harsh works in his research group at the NGPRL. Harsh has completed his Bachelor of Technology in Agricultural Engineering from the Sam Higginbottom University of Agriculture, Technology, and Sciences (formerly known as Allahabad Agricultural Institute), Uttar Pradesh, Prayagraj, India. His masters research focuses on digital image processing of unmanned aerial vehicle (UAV) images, which includes determination of plant row identification, plant count, and weed identification and mapping. In his previous research, he had developed an instrument prototype to monitor the soil moisture on the cloud platform and to automate the irrigation using sensors with the Arduino micro-controller. Apart from the research work, he worked as a field officer in the Sales Department of Massey Ferguson (tractors and farm equipment manufacturer) in India. In his free time, he loves to play cricket and badminton, and enjoys reading mythological books.

During his stay at NGPRL, he will be developing algorithms using open source platforms to analyze the UAV images for different applications in agriculture in the North Dakota Corn Council project. He will also be involved in other research activities of image processing, such as synthesis of plant count literature, preparing a useful dataset of the commonly found weeds in North Dakota.

Raina Hanley

Raina Hanley, Agricultural Science Research Technician, lives 15 miles north of New Salem on the family farm where they raise crops and beef cows. She graduated from Bismarck State College with a double major in Agribusiness and Agronomy. She attended Dickinson State University and received her Bachelor of Science degree in Range Management. During the summers between school, she worked at the NGPRL on summer staff and as intern. She enjoys spending time with family and in all outdoor activities.

Eric Antosh

Eric Antosh, Agricultural Science Research Technician, is originally from northeastern Pennsylvania. He holds a bachelor's degree from SUNY College of Environmental Science and Forestry in Syracuse, NY where he spent time working on the American Chestnut Research and Restoration Project. He then made his way to New Mexico State University where he did masters research on cover crops and their effects on weed communities and soil properties. This research was able to produce a publication in Agronomy Journal, with another in review at Weed Technology Journal. When he is not working, you can most likely find him hiking/backpacking, biking, and skiing.

Jackie Zachmeier

Jackie (Jacqueline) Zachmeier, Financial Technician, is originally from North Dakota. She holds an MBA and bachelor degrees in Accountancy and Financial Management from the University of North Dakota in Grand Forks. Jackie worked in public accounting performing payroll, accounting, tax and consulting work for individuals and business clients before joining USDA. When she is not working, you can find her playing with her kids, basset hound and chickens or reading a book!

Congratulations to Jennifer Carter, who serves on the ARS Partnerships for Data Innovation team. The team was recently presented with the Special Achievement in GIS award from ESRI. The President of ESRI indicated that the ARS effort "stood out from more than 100,000 others", so this is a significant achievement.