NC-1210 Report

Short-term Outcomes.

- Adoption of a technology. NC-1210 members wrote and won a $4,000,000 grant from the On-Farm Innovation Trials program of the NRCS Conservation Innovation Grant program (award number NR213A750013G021). The project title is "Improving the Economic and Ecological Sustainability of US Crop Production through On-Farm Precision Research." With funding from that grant, several NC-1210 members developed beta version of a cloud-based software system called the On-Farm Experimentation Prescription Generator that allows farmers and consultants to design and implement their on on-farm precision experiments. The International Society of Precision Agriculture has several invited NC1210 members and their graduate research assistants to their annual meeting in Minneapolis, June 27-29, 2029 to conduct two training sessions to teach farmers, crop consultants, and researchers to use the tool. NC-1210 members also won an $80,000 Western SARE PDP grant to hold training sessions in Denver, June 8-9, 2022, to teach university extension personnel to use the trial design software. Recipients of this training will have an important tool for improving fertilizer and seed application strategies, which will bring both economic and environmental benefits.
- NC-1210 members developed an R-based computational system, called DIFM-HQ that partially automates the generation of trial designs, the management and analysis of trial design data, and the writing of reports to farmers on the outcomes of the experiments. NC-1210 personnel are now using this system as a foundation for scaling up their cyber-infrastructure in a system based on the Oracle cloud.

Outputs

Here is a link to our trial design software.

Bruce Maxwell OFPE Video: https://www.youtube.com/watch?v=2_bdDTpKOwk&t=2s

Hannah Duff. PhD Student MSU:

Ecological Refugia in Agricultural Landscapes
ArcGIS Story Map
Hannah Duff
https://arcg.is/1SKLPP

Du, Q., T. Mieno, and D.S. Bullock. "Economically Optimal Nitrogen Side-dressing Based on Vegetation Indices from Satellite Images Through On-farm Experiments." Submitted. *Precision Agriculture*, August 2021.

Duff, H., Hegedus, P., Loewen, S., Maxwell, B. D. 2021. Precision Agroecology Journal of Sustainability 2: *Accepted 12/20/21*

Li, N., D.S. Bullock, C. Butts-Wilmsmeyer, L. Gentry, G. Goodwin, J. Han, N. Kleczweski, N.F. Martín, P. Paulausky, P. Pistorius, N. Seither, N. Schroeder, and A.J. Margenot. "Distinct Soil Health Indicators Are Associated with On-farm Variation in Maize Yield and Tile Drain Nitrate Losses across Contrasting Nitrogen Applicaiton in Central Illinois." Working paper, August 2021.

Mieno, T., X. Li, and D.S. Bullock. "Evaluating Site-specific Nitrogen Management by Applying Geographically Weighted Regression to On-farm Precision Experimentation Data." Working paper, July 2021.

Paccioretti, P., M. Córdoba, C. Bruno, F. Giannini Kurina, D.S. Bullock, and M. Balzarini. "Statistical Modeling for On-farm Experimentation with Precision Agricultural Technology." In press, *Agronomy Journal*. July 2021.

Presentations

Honors Presents Lecture Series
STEM Storytellers: Good Science, Great Stories
To Farm or to Conserve: Two Halves of a Whole Story
Hannah Duff
March 31, 2021
Virtual

Department of Land Resources and Environmental Sciences Student Research Colloquium
Predicting the Effects of Climate Change on the Invasion Potential of an Annual Winter Plant in Yellowstone National Park
Hannah Duff
April 15, 2021
Virtual

STEM Storytellers Final Event
To Farm or to Conserve: Two Halves of a Whole Story
Hannah Duff
April 20, 2021
Virtual
Ecological Society of America Annual Meeting
Ecological Refugia in Agricultural Landscapes
August 3, 2021
Hannah Duff
Virtual

Grand Challenges in Ecology and Environmental Sciences: The Grand Salon
Evolution of Thought on the Evolution of Species
November 5, 2021
Hannah Duff
Bozeman, Montana

Does Organic Farming Have Anything to Gain From Precision Agriculture?
Montana Organics Association Annual Conference
Bruce Maxwell, Paul Hegedus, Sasha Loewen and Hannah Duff
December 3, 2021
Virtual

Montana Organics Association Annual Conference
Tradeoffs of Hosting Biodiversity on Your Farm
Hannah Duff
December 6, 2021
Virtual

Sasha Loewen. PhD Student
Loewen, S. (2021). [Review of *Dust Bowls of Empire: Imperialism, Environmental Politics, and the Injustice of "Green" Capitalism*, by H. Holleman]. *Agricultural History*, *95*(3), 546–548. https://www.jstor.org/stable/10.3098/ah.2021.095.3.546

Title: Two-dimensional deep regression for early yield prediction of winter wheat
Authors: Giorgio Morales and John W. Sheppard
Link: https://spie.org/future-sensing-technologies/presentation/Two-dimensional-deep-regression-for-early-yield-prediction-of-winter/11914-100

"The Value of Conducting On-farm Field Trials Using Precision Agriculture Technology" (*Invited Speaker)	**Big Ag Data Conference**	**Bullock, D.S., and T. Mieno**	**Davis, California**	**1/10/20**
"Estimating Yield and Water-Quality Response Functions using On-Farm Precision Experimentation, Spatially-Intense Soil Sampling, and Hyperspectral Imagery"	**University of Illinois Center for Digital Agriculture Workshop**	**Bullock, D.S., L.F. Gentry, A. Margenot N.F. Martín, and P. Kumar**	**Urbana**	**2/28/20**
"Using Precision Technology to Conducxt On-farm Research Trials for Data-Intensive Farm Management" (*Invited Speaier)	**56th Annual Illinois Corn Breeders' School**	**Bullock, D.S., and T. Mieno**	**Champaign**	**3/2/20**
"Working with the Data-Intensive Farm Management Project"	**Christiansen Land & Cattle Company**	**Bullock, D.S.**	**Remote**	**4/4/20**

(*Invited Speaker) "Using On-farm Experimentation and Satellite Imagery to Estimate Economically Optimal Nitrogen Side-dressing Rates"	ASA/CSSA/SSSA Annual Meetings, "Symposium--Coupling the Power of Digital Agriculture, Experimental Design, and Modeling"	Bullock, D.S.	Phoenix, AZ	11/8/20 - 11/11/20
"Overview of the Data-Intensive Farm Management Program" (*Invited Speaker)	NAMPO Ag Expo 2020 (Virtual)	Bullock, D.S.	Pretoria, South Africa	9/9/20
"On-Farm Precision Experimentation in the Data-Intensive Farm Management Program" (*Invited speaker)	(invited) AAEA Track Session on Precision Agriculture	Bullock, D.S.	Virtual	9/10/20
"An Economic Evaluation of Site-specific Input Application Rx Maps"	3rd INFER Online Symposium on Agri-Tech Economics for Sustainable Futures	Mieno, T., and D.S. Bullock	Newbury, UK (virtual)	9/21/20
"Using On-farm Precision Experimentation to Optimise Seed and Nitrogen Fertilizer Rate Management in the Free State, South Africa"	3rd INFER Online Symposium on Agri-Tech Economics for Sustainable Futures	Delport, M., D.S. Bullock, et al.	Newbury, UK (virtual)	9/21/20
"Overview of the Data-Intensive Farm Management Project and Possible Paths for Helena-DIFM Collaboration"	Helena company	Bullock, D.S.	Virtual	11/20/20
"Empirical Assessment of Interactions among Genetics, Environmental Factors and Managed Inputs in Corn Yield Response"	AIFARMS	Moose, S.P. and D.S. Bullock	Virtual	12/17/20
"Economic and Ecological Sustainability of Crop Production through On-farm Precision	(invigted) Digital AgriTech 2021 Virtual Summit	Bullock, D.S.	Virtual	2/16/21

Experimentation". (*Invited Speaker)				
"DIFM-CIGOFT: Improving the Economic and Ecological Sustainability of US Crop Production through On-Farm Precision Experimentation"	NRCS State Agents	Bullock, D.S.	Virtual	6/22/21
"Economically Opitmal Nitrogen Side-dressing Based on Vegetation Indices from Satellite Images through On-farm Experiments"	4th Symposium on Agri-Tech Economics for Sustainable Futures	Du, Q., and D.S Bullock	Virtual	9/20.21
"Contributing to an International Cyber-infrastructure for On-farm Precision Experimentation" (*Invited Speaker)	OFE2021 (on-farm experimentation 2021)	Bullock, D.S.	Montpellier, France	10/13/21
"Contributing to an International Cyber-infrastructure for On-farm Precision Experimentation"	PhenoRob, University of Bonn	Bullock, D.S.	Bonn, Germany	10/18/21
"On-Farm Precision Experimentation: A DIFM and Community College Cooperative Research and Education Program"	Representatives from community college precison ag programs	Bullock, D.S.	Virtual	12/18/21
"Using Precision Technology to Conduct On-farm Research Trials for Data-Intensive Farm Management" (*Invited Speaker)	Kernel and MHP companies (large Ukrainian landholders and farms)	Bullock, D.S.	Virtual	12/30/21
"Modern Approaches to Estimating Site-specific Profit-maximizing Nitrogen Application Strategies" (*Invited Speaker)	International Scientific-Practical Online Conference on the Topic of Nitrogen Nutrition	Bullock, D.S.	Virtual	1/12/22

"How Farmers Can Increase Profits Using Precision Technology to Conduct Research on Their Own Fields" (*Invited Speaker)	**Webinaires MAPAQ Grandes Culture (Seminar series put on by the Quebec Ministry of Agriculture, Fisheries and Food. Approximately 450 farmers, crop consultants, and agronomists registered.**	**Bullock, D.S.**	**I appeared by Zoom. Conference was held in-person in Quebec.**	**2/9/22**

In Review:
Loewen, Sasha; Maxwell, Bruce (2021). On Farm Precision Experimentation in Organic Dryland Grain Production. *OFE2021 Proceedings*

Awards:

1. Soils and Crops Graduate Student Travel Award - $250 – March 2021
2. Montana View Remote Sensing Fellowship - $1500 – April 2021
3. Big Sky GeoCon GIS map contest, 2nd place - $25 – April 2021

Presentations:

Data Intensive Adaptive Management in Organic Dryland Grain Production
Soils and Crops Conference, University of Saskatchewan, March 2021
Online oral presentation
Sasha Loewen, Bruce Maxwell

On Farm Precision Experimentation in Organic Dryland Grain Production
Big Sky GeoCon by Montana Association of GIS Professionals, April 2021
Online oral presentation
Sasha Loewen, Bruce Maxwell

Applying Precision Seeding Rates in Organic Dryland Grain Production
Montana State University Department of Land Resources and Environmental Sciences Colloquium, April 2021
Online poster presentation
Sasha Loewen, Braedon Lineman, Bruce Maxwell

Data Intensive Adaptive Management in Organic Grain Production
MontanaView Remote Sensing Fellowship Symposium, April 2021
Online oral presentation
Sasha Loewen, Bruce Maxwell

On Farm Precision Experimentation in Organic Dryland Grain Production
Farm Centric On Farm Experimentation 2021, October 2021
Online oral presentation

Sasha Loewen, Bruce Maxwell

Organic On Farm Precision Experimentation
Precision Agriculture Research Association Annual Meeting, December 2021
Online oral presentation
Sasha Loewen, Bruce Maxwell

Precision Nitrogen and Weed Management in Organic Grain Systems
Montana Organic Association Student Summit, December 2021
Online oral presentation
Sasha Loewen, Bruce Maxwell

Paul Hegedus. PhD Student and DIFM Research Associate
Hegedus, P.B., & Maxwell, B.D. (2021). On-farm experiments to optimize site-specific application of nitrogen fertilizer rates to maximize producer profits. Oral. Montana Fertilizer Advisory Council, Montana State University, Bozeman, MT, January 12th.

Hegedus, P.B. (2021). MSU EAL Costech 4010 Data Report Generator for Carbon and Nitrogen Samples. Website Application. Published. January 22nd.
https://paulhegedus.shinyapps.io/msucostech_report_app/

Maxwell, B.D. & Hegedus, P.B. (2021). Data Intensive Agriculture. Oral. Washington State University Fertility Webinar, Online, February 4th.

Hegedus, P.B., & Maxwell, B.D. (2021). What's the cost…? Or Profit?!. Oral. Washington State University Fertility Webinar, Online, February 4th.

Hegedus, P.B. (2021). SampleBuilder: An R package for creating field sampling designs. Software. Published. May 26th. https://github.com/paulhegedus/SampleBuilder.git

Hegedus, P.B. (2021) Optimizing Nitrogen Fertilizer Management Based on Site-Specific Maximized Profit and Minimized Pollution. Oral. Montana State University, Webinar, October 1st.

Hegedus, P.B. & Maxwell, B.D. (2021). OFE is most meaningful to farm management decisions if there is significant farm-to-farm variation. Oral. OFE2021 – ISPA, Online, October 13th.

Hegedus, P.B. & Maxwell, B.D. (2021). OFE is most meaningful to farm management decisions if there is significant farm-to-farm variation. Conference Proceeding. OFE2021 – ISPA, October 14th.

Hegedus, P.B. (2021). Harnessing digital data to supplement farmer knowledge. Oral. Montana Organic Association, Online, November 29th.

Hegedus, P.B. (2021). Analysis and Insights From 2021 On-Farm Precision Experimentation. Oral. PARA – Precision Agriculture Research Association, Online, December 6th.

Hegedus, P.B. (2021). OFPE: An R package for automating data management, analysis, and experimental design of On-Farm Precision Experiments – v1.7.23. Software. Published. December 19th.
https://github.com/paulhegedus/OFPE.git

Morales, G., Sheppard, J.W., Hegedus, P.B., Maxwell, B.D. (2021). Two-dimensional Deep Regression for Early Yield Prediction of Winter Wheat. Paper. Precision Agriculture, In-Review, December 20th.

Hegedus, P.B., & Maxwell, B.D. (2021). Rationale for field specific on-farm precision experimentation. Paper. Agriculture, Ecosystems, & Environment, In-Review, December 21st.

Hegedus, P.B. & Maxwell, B.D. (2021). Assessment of empirical crop modeling approaches for on-farm precision experimentation. Paper. TBD, In-Works, December 31st.

Hegedus, P.B., & Maxwell, B.D. (2021). Constraint of data availability on the predictive ability of crop response models developed from on-farm precision experiments. Paper. TBD, In-Works, December 31st.

Data: NC-1210 members worked in the DIFM research project to run over seventy on-farm precision experiments in thirteen US states. Approximately seventy more trials are being designed for the 2022 growing season. Data from all these trials has been analyzed, and reports of the research results and implications are currently being sent to the participating farmers.

Activities

NC-1210 members have been designing and running on-farm precision experiments with participating farmers, managing the data, analyzing the data, and reporting research results.

Graduate Student Activities:

Amy Peerlinck: Amy has been focused on developing trial-design software for managing nitrogen and seeding rates by creating a web application that is easy for farmers and crop consultants to use. She has incorporated a variety of design methods into the tool, including a bi-objective genetic algorithm to balance stratification and smooth transitions in rates. She is also working on developing multi- and many-objective optimization algorithms and tools to support the longer-term objectives of creating economically optimal input rate prescriptions.

Giorgio Morales: Giorgio has been investigating and developing methods for yield prediction to support developing economically optimal input rate prescriptions. In addition to assessing the performance of standard models, such as generalized additive models and random forests, he has developed a novel 2-dimensional regression deep neural network based on his prior research in deep learning. His network adapts his Hyper3DNet convolutional network to handle multi-modal inputs and produce regressed predictions over a two-dimensional patch. The output of the adapted network, referred to as Hyper3DNetReg, also generates prediction interval estimates automatically for each of the outputs in the patch.

Alison Kleffner: has been working to develop the user interface for the trial design software in Shiny. She has laid out the UI and is now working to connect Amy P's Python code to the user interface so that it runs as Amy P. designed it to run.

Paul Hegedus (PhD student): has conducted research by conducting on-field nitrogen fertilizer experiments in rain-fed winter wheat in Montana using variable rate application technology. The data from the experiments were analyzed to identify within field site-specific economic optimum nitrogen fertilizer rates to maximize field scale net returns and fertilizer efficiency to reduce pollution and soil acidification. Paul has built a database, analytical engine and simulation models that automate a decision support system for nitrogen fertilizer application.

Sasha Loewen (PhD student): is conducting research to optimize site-specific wheat seeding rates and previous cover crop seeding rates that maximize field net returns and minimize weed population spread.

Hannah Duff (PhD student): is conducting research to determine the agronomic and economic services from portions of fields taken out of production (based on low net returns) and replaced with native vegetations to act as ecological refuges.

Milestones

- Design and implement 2022 trials
- Move all DIFM Data into the Oracle database and management system
- Automate the report-writing system
- Develop a wireframe of the "decision tool" software
- Hold International OFPE conference in Miami, January 2023
- Hold meetings to "test-drive" the software with farmers and crop conultants
- Have an early but working version of the "Analytical Engine" that uses artificial intelligence, statistics, and crop modeling to take analytical management insights out of the data