2024-2025 Multistate Research Activity

NCCC-31

Ecophysiological Aspects of Forage Management

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APPENDIX D SAES-422
Multistate Research Activity
ACCOMPLISHMENTS REPORT

Project/Activity Number: NCCC-31
Project/Activity Title: Ecophysiological Aspects of Forage Management
Period Covered: July 2024 to August 2025
Date of This Report: June 27, 2025
Annual Meeting Date(s): Spring Hills, TN, 29 April – 1st May 2025

2025 ANNUAL MEETING

Brief summary of minutes of annual meeting:
President: Dr. Marta Moura Kohmann (Wisconsin)
Secretary: Dr. Shelby Gruss (Iowa)
Host: Dr. Renata Oakes (Tennessee)

Meeting Notes – 29 April – 1st May 2025 – Spring Hills (TN)

Participants (PIs): 13, representing 13 states

Marisol Berti (ND) | Kim Cassida (MI - online) | Shelby Gruss (IA - online) | Bill Lamp (MD) | Jennifer McAdam (UT) | Marta Moura Kohmann (WI) | Renata Oakes (TN) | Juan Romero (ME - online) |Guojie Wang (PA) | James Kells (MI) | Rebecca McCulley (KT) | Jeff Volenec (Indiana - online) | Marilia Chiavegato (OH)

Participants (undergraduate and graduate students): 2, representing Tennessee

MEETING AGENDA AND BUSINESS MEETING NOTES

Monday April 28

Arrivals / Check-in at the hotel

Dinner on your own

Tuesday April 29

Field Tours

9:00-9:30: Meet in front of the main office (1000 Main Entrance Dr., Spring Hill, TN 37174)

9:30-11:00 Tour experimental sites at MTREC

1. Organic Corn – Living Mulch

2. Alfalfa/Fescue

3. Triticale

4. Precision Livestock

11:00-12:30: Lunch

1:00: Meet in front of the main office for farm tour

Address:

Deer Valley Farm

11 Fred Clark Lane

Fayetteville, TN 37334

2:00: Arrive at Deer Valley Farms

4:30: Back in vehicle

State Reports

9:00-9:05 – Welcome and Introductions – Renata Oakes

9:05-9:25 – Administrative Advisor Report – James Kells

9:25-9:45 – Project Renewal Proposal Edits – Bill Lamp

9:45-10:45 – Business Meeting

[1] Recruit more participants to NCCC31. Several participants have changed positions, and in addition, there are many new hires across the US who would greatly contribute to this group. This committee has also been historically composed of members from various states outside the North Central region, and recently, we noted some states under the North Central region do not have a representative in NCCC31, or the current representative is not registerd. These factors are driving the NCCC31 to act intentionally in recruiting new members.

We are seeking representatives from the states listed below, accompanied by a possible nominee and a current NCCC31 member volunteering for a direct invite.

Alabama (LeAnn Dillard; Renata Oakes will contact her)

Arkansas (Dirk Phillipp will be contacted by Marisol Berti)

Florida (Marcelo; Marta Kohmann will contact him)

Georgia (Forage weed scientist Robert Stougard; will be contacted by Jim. Lisa Baxter and Jennifer Tucker will be contacted by Renata Oakes)

Idaho (Pramod Acharya; will be contacted by Marilia Chiavegatto)

Iowa (not registered; Shelby Gruss)

Kansas (Doo-Homg Min, suggested by Marison Berti and will be contacted by Marisol Berti. In addition, Romulo Lollato will also be invited by Renata Oakes)

Maine (Juan Romero is the University of Maine representative; we will also invite Jaime Garzón as an to contribute)

Minnesota (not registered; Jake Jungers),

Missouri (Carlson Robbins, suggested by Jenniffer McAdam)

Montana (Hayes Goosey, will be contacted by Jennifer)

Nebraska (not registered; John Guretzky)

New Mexico (Mark Marsalis; include Anwar in the email; will be contacted by Renata)

North Carolina (Miguel Castillo; Marta Kohmann will contact him)

Oregon (Sarkan Ates is interested; will be contacted by Jennifer McAdam)

South Carolina (Liliane Silva; Marta Kohmann will contact her)

South Dakota (Sarah Baulder; and Christopher Graham; will be contacted by Marisol Berti)

Tennessee (not registered)

Texas (Jamie not registered)

Virginia (Ben Tracy – should we contact John Fike?)

Washington (currently recruiting)

Wyoming (Clint Beiermann; Guojie will contact him)

We propose writing an invitation email to invite new members.

We will invite Juan Romero (Maine) to be secretary. Backup secretary is Guojie Wang. Juan accepted the nomination.

Location for the next meeting: Marilia Chiavegato volunteers to host at Ohio (Columbus). We will target the weeks of 8th June , 15th June, of the 20th July, and 27th July. Marilia will send a doodle pool. Marisol and Renata will share the budget for their events to help Marilia plan the costs associated with hosting.

10:50-11:00 – Coffee Break

11:00-11:20 – Kentucky State Report, Rebecca McCulley

11:20-11:40 – Maryland State Report, Bill Lamp

11:40-12:00 – Michigan State Report, Kim Cassida (zoom)

1:30 – Meet back at the conference room

1:40-2:00 – Iowa State Report, Shelby Gruss (zoom)

2:00-2:20 – Indiana State Report, Jeff Volenec (zoom)

2:20-2:40 – North Dakota State Report, Marisol Berti

2:40-3:00 – Ohio State Report, Marilia Chiavegato

3:00-3:20 – Pennsylvania State Report, Goujie Wang

3:20-3:40 – Tennessee State Report, Renata Oakes

3:40-4:00 – Maine State Report, Juan Romero (zoom)

4:00-4:20– Utah State Report, Jennifer Macadam

4:20-4:40 - Wisconsin State Report, Marta Kohmann

Arkansas
University of Arkansas (Philipp)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The group from the University of Arkansas is engaged in applied research and extension activities pertaining to the use of native and introduced annuals, perennials, warm and cool season forages. Current activities, based on federal and state funding, have focused on determining soil water retention under grazing to different canopy heights, forage establishment and growth in wooded areas, native grass establishment, and prairie reconstruction for roadside management and habitat restoration.

2. New Facilities and Equipment

None

3. Unique Project-Related Findings

A small-plot, native multi-species ("prairie") restoration experiment started several years ago was adjusted after initial failure in 2021/2022 and has been continued during the reporting period 2024-2025. We were able to establish a successful planting-date trial (fall of 2023, winter of 2023/2024, and spring of 2024) that is showing the effects of different establishment techniques (drill, broadcast, and hydroseeded) and the application/non-application of a preemergence herbicide. Species assessments showed that black-eyed susan, rattlesnake master, various milkweeds, ashy sunflower, partridge pea, Illinois bundleflower, and most grasses (switchgrass, little bluestem, big bluestem, sideoats grama, little bluestem) were the most frequent species recorded during initial assessments in spring of 2024. During spring of 2025, it appeared that some species were much less frequently present while blackeyed susan emerged as the dominant forb species.

4. Accomplishment Summaries

During the last reporting period, we finished/started and/or continued the major following projects:

1) Sheep grazing effects on soil water status in cool season perennial pastures, (finished)
    a. Data currently being evaluated and analyzed
2) AR DOT Roadside project, (continued and extended)
    a. Extended into planting-date experiments and nurse crop trial
3) Establishment of savannah-type ecosystems (started)
    a. Ground preparation (tillage) for native grass establishment and tree cover completed
    b. Native grasses were seeded end of May/early June 2025
    c. Assessment of tree species and number/acre are underway
        i. Southern red oak, white oak, and burr oak are being considered
4) Continued cooperation on agroforestry project spearheaded by USDA-ARS Ames, IA
    a. Site preparation for native grass planting in spring of 2025

i. Repeated herbicide application

b. Tree thinning and maintenance

Impact Statement

Title: Restoration of Prairie Plant Communities

Problem

Prairie plant communities offer unparalleled ecosystem benefits such as high plant diversity, wildlife habitat, and the ability to capture large amounts of carbon that can be translocated to deep soil layers for long-term immobilization and storage. There are no clear prairie restoration guidelines available for Arkansas, largely because restoration efforts have been primarily made in states of the upper mid-west, although Arkansas featured considerable tracts of native grasslands in the past.

Response

Several basic agronomic trials were established to evaluate establishment strategies for these multi-species, native plant mixes. Experiments initially included 3 different sites with various hydrological regimes; during 2023/2024 we added planting date trials and experiments to determine the usefulness of nurse crops to help prairie plants establish under less weed pressure. A new core experiment compares planting dates (April, October, and February), planting method (drill, broadcast, hydroseeded), and use of preemergence herbicide at planting (Plateau® +/-). Data was collected using a modified Shannon Wiener method by counting present species (max 6 grasses and 20 forbs) per plot multiple times throughout the growing season. Experiments were established in such a fashion that allows for a 5 to10-year monitoring period as this is necessary for assessing prairie long-term establishment success.

Results

The application of a preemergence herbicide has an immeasurable positive effect on establishment success. Although the total number of established native grasses and forbs is still small as full emergence can take a few years, plots treated with Plateau® + are very clean and almost free of non-native plants. All establishment methods resulted in acceptable emergence, and fall plantings favor forbs of over grasses.

Value

Restored prairie plant communities can have extraordinary impacts on ecosystems health through the provision of multiple services including support of livestock grazing and meat production. Native, multi-species plant communities can maintain the water quality of adjacent streams, support a host of small animal and insect species, provide ground-nesting bird habitat and food, and are aesthetically pleasing in rural landscapes.

Funding

Arkansas Department of Transportation.

5. Published Written Works

Peer-reviewed:

Ashworth, A.J., A. Avila, H. Smith, T.E. Winzeler, P. Owens, C. Flynn, P. O'Brien, D. Philipp, J. Su. 2024. Predicting Spatiotemporal Patterns of Productivity and Grazing from Multispectral Data Using Neural Network Analysis based on System Complexity. Agroecosyst Geosci Environ. 7:e20571 https://doi.org/10.1002/agg2.20571.

Niyigena, V., K.P. Coffey, D. Philipp, M.C. Savin, J. Zhao, H.D. Naumann, J.M. Diaz, S.P. Park, R.L. Rhein, S.L. Shelby. (2024). Intake, digestibility, rumen fermentation and nitrogen balance in sheep offered alfalfa silage with different proportions of the tannin-rich legume sericea lespedeza. *Anim Feed Sci Technol* 308, 115863.

Abstracts:

Peter L O'Brien, Amanda J. Ashworth, Phillip R. Owens, Andrew L. Thomas, Dirk Philipp. 2024. Long-term silvopasture increases C storage and improves soil physical health compared to conventional pasture management. ASA-CSSA-SSSA Annual Meeting, San Antonio, TX.

Outreach publications:

Kubesh, J., K. Simon, D. Philipp. Planting oats for forage FS3151R (revised)

Dept of Animal Science E-News/Dairy-News:
Philipp, D. (2024). New year – new opportunities
Philipp, D. (2024). Tree-covered landscapes for ruminant grazing
Philipp, D. (2024). Pasture fertilization and trying to make your dollars count
Philipp, D. (2024). Inter-seeding legumes into pastures – pros and cons
Philipp, D. (2024). How to deal with muddy pastures.
Philipp, D. (2024). Diversity of forages and a flexible management approach help mitigate droughty periods.

Arkansas Beef and Forage Corner:
Philipp, D. (2024). Abundant moisture creates challenges and opportunities
Philipp, D. (2024). Water conservation: Good for pastures and livestock

Other outlets:
Philipp, D. and R. McGeeney. (2024). A long-term strategy for avoiding muddy pastures
Philipp, D. and R. McGeeney. (2024). The perennial puzzle: Deciding whether to fertilize your pasture

6. Scientific and Outreach Presentations

Philipp, D. (2024). Forage solutions for highland cattle in the Ozark Mountains. Missouri Highland Cattle Association, Sheepdog Heroes Ranch, Arnett, MO. (non-refereed)

7. Collaborative Grants

- Richardson et al. (Philipp Co-PI): Developing a sustainable approach to roadside vegetation management in the State of Arkansas
  - Continuing research trials
- Jagadamma, S. et al. (Philipp Co-PI): Native Warm Season Perennials: An Enduring Solution To Summer Drought And Slump For Fescue Belt Organic Forage Production
  - USDA, Organic Agriculture Research & Extension Initiative; ~$105,00
- Grassland Partnership; joint research and extension project among 9 states; total volume $30 mil.

8. Graduate Students

- Kolten Wright, MS Student (Univ. of Arkansas, Department of Animal Sciences), advisee
- Sarah Paschal, MS Student (Univ. of Arkansas, Department of Horticulture), thesis committee member

Indiana
Purdue University (Volenec)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget:
Work focuses on improving our understanding of physiological and ecological mechanisms underpinning forage crop responses to environment, including climate change, and ever-evolving crop management strategies.

2. New Facilities and Equipment:
None

3. Unique Project Related Findings
a) Work was initiated to improve our understanding of diagnostic performance of soil and tissue test results using receiver operating characteristics (ROC) analysis.
b) A long-term longitudinal study is investigation the rate and extent of C accumulation in soils with ~25 years of continuous cropping as corn-soybean rotations, continuous corn, or in perennial systems including a restored native prairie or perennial bioenergy systems including switchgrass and Miscanthus.
c) Working with stakeholders, funders, and researchers in soil fertility and plant nutrition guidelines for common minimum datasets and data stewardship in evaluating the agronomic performance and environmental impact of enhanced efficiency fertilizers were developed.
d) A systematic review with meta-analysis is underway to characterize the interaction of N fertility on responses of C_3's to elevated CO_2 using datasets exclusively generated at Free-air CO_2 Exchange (FACE) global network. While most of the datasets focus on cereals, the finding should inform how climate change will impact yield and composition of C_3 forages that are under-represented in the FACE network.
e) Work is underway to determine the physiological basis for persistence of kura clover in mulch cropping systems. Rows of kura clover, Spredor 5 alfalfa (with rhizomes), and a conventional taprooted alfalfa were established in 2023. Plants were defoliated or sprayed with a herbicide (both approaches used to limit competition in mulch cropping) and taproot and rhizome C and N reserves compared to that of intact plants.

4. Accomplishment summaries:
Diagnostic Performance of Soil and Tissue P and K Testing.

Soil testing remains the primary tool used to inform fertilizer management in North America, but when and how deep to sample soils is currently debated particularly in perennial and no-till systems where nutrient stratification occurs. In addition, the impact of co-limiting nutrients on identification of critical values is anticipated, but poorly characterized. Our objective was to determine the effectiveness of soil test P (STP) and K (STK), and herbage P and K as predictors of alfalfa performance. We also evaluated specificity and sensitivity of these predictors using receiver operating characteristics (ROC) analysis. Plots were fertilized with a factorial combination of four P and five K rates. Soil samples in 5-cm increments were obtained after each forage harvest from May 2000 to Sept. 2004 and analyzed for STP and STK. Tissue P and K were also analyzed. Linear-plateau (LP) regression was used to determine critical STK

and STP values as influenced by soil depth, month and year, and critical tissue P and K concentrations. The confounding effect of P limitations on critical STK levels, and K limitations on critical STP levels was also assessed. High forage yields were obtained when at least 200 kg K and 25 kg P were applied per ha. Including progressively deeper soil increments in the LP regressions altered the slopes and join points (“critical values”) as expected, but did not impact plateaus or R2-values. Critical values of the LP regressions were generally similar for analyses conducted by month (averaged over years) and years (averaged over months). Excluding P-limited plots from the K LP regression and K-limited plots from the P LP regression improved model performance. This improvement was confirmed with ROC analysis where diagnostic accuracy improved from "sufficient" to "good" classes. ROC analysis also indicated that herbage K was a much better predictor of alfalfa performance than STK in P-limited plots. It also indicated that herbage P could not predict alfalfa yield if data from K-limited plots were included, but both STP and herbage P were "sufficient" to "good" predictors of alfalfa yield if low-K plot data were removed. The combination of L-P regression (provides critical values) and sensitivity/specificity (ROC) analysis was important for understanding the utility of soil and herbage K and P in a fertilizer recommendation framework for alfalfa.

Soil Organic Carbon Accumulation Rates in Perennial vs Annual Cropping Systems.

Conventional cropping systems are often linked to soil organic carbon (SOC) depletion and soil degradation. Our objective was to evaluate the temporal dynamics of total organic carbon (TOC) and nitrogen (TN) in the soil profiles of a long-term experimental site following the transition from annual to perennial systems. We compared soil C: N balance and stocks over time among cropping systems, including conventionally managed continuous maize, corn-soybean rotations (CSR), and native prairie as the control, applied over 30 years, with perennial grass systems (miscanthus and switchgrass) following 10 years of transition from CSR. Soils were sampled to a depth of 1 m in 0.15 m increments and analyzed for profile cumulative TOC and TN across treatments, with equivalent soil mass corrections performed prior to these calculations. Statistical analysis of changes over time was completed using the R package 'meta'. Overall, TOC was significantly higher in perennial compared to annual systems, with the highest levels found in the topsoil (0–30 cm) across all treatments. Miscanthus and switchgrass exhibited more consistent TOC storage and prairie exhibited consistently lower TN concentrations throughout the full soil profile. Continuous corn showed an increase in TN and a decrease in TOC. After 10 years of transition, switchgrass recorded the highest increase in TOC among all treatments, while TN remained relatively stable. In contrast, miscanthus exhibited increases in both TOC and TN. Evaluating the influence of long-term cropping systems, combined with information from transitioning conventional systems to perennial, can help develop appropriate and cost-effective agricultural management practices that enhance soil health, guide farmer decision-making, and ultimately advance food and nutritional security.

Minimum Datasets and Data Standards/stewardship for Research Focused on Enhanced Efficiency Fertilizers.

There are many fertilizer additives and alternatives that aim to increase plant nutrient use efficiency and reduce nutrient losses to the environment, here referred to collectively as enhanced efficiency fertilizers (EEFs). However, there is often insufficient published scientific field trial results across a variety of locations, climates, soils, cropping systems, and management scenarios to prove their efficacy and conditions for use. Guidelines for common minimum

datasets and data stewardship in evaluating the agronomic performance and environmental impact of EEFs are needed for researchers to follow. Such guidelines will improve hypothesis testing centered on product efficacy and provide producers with guidance on how these technologies function and perform when integrated with other management practices within the 4R Nutrient Stewardship Framework. A scientific committee was formed to develop a set of protocol guidelines for evaluating EEFs in replicated, plot-based field trials on an international scale. The guidelines are composed of experimental design and core metadata, crop and soil analyses, environmental loss measurements, and data stewardship. This approach allows for flexibility and adaptability depending on the trial location, objectives, infrastructure capacity, product type, and depth of understanding of the potential EEF efficacy while supporting consistency and compatibility in experimental design and data collection to support data integration, analysis, and reuse leading to large-scale impact and end-user confidence.

Crop Responses to Free-Air CO_2 Enrichment (FACE) and Nitrogen Fertilization: A Systematic Review and Meta-Analysis.

Elevated CO_2 (eCO_2) is expected to enhance yields of C_3 plants, however, quantities of fertilizer required to support yield increases and ensure grain quality and protein content in a changed climate are uncertain. Our objective was to evaluate the yield response of staple crops under eCO_2 as compared to ambient CO_2 (aCO_2) concentrations in free air CO_2 enrichment (FACE) studies with multiple levels of nitrogen (N) fertilizer. We conducted a systematic review of the primary literature and extracted treatment mean and variance data for all target crop FACE experiments with two or more N rates. Studies were categorized by N rate and analyzed by meta-analytical (MA) statistics, including Network MA, to identify and compare the interactive effects of N and eCO_2 on yield, grain quality and N use efficiency (NUE). As expected, maize, a C_4 plant, had no yield advantage under eCO_2 fertilization. However, an eCO_2 yield response was observed under drought stress likely reflecting the indirect effect of reduced stomatal conductance and improved water relations under eCO_2. Averaged over N rates, yields of all six C_3 crops increased when grown at eCO_2 versus aCO_2. For rice, network MA detected higher and similar yield increases under eCO_2 at N_2 (11–20 g m^{-2}), N_3 (21–30 g m^{-2}), and N_4 (≥31 g m^{-2}) when compared to N_2 (currently recommended N rate) at aCO_2 but NUE was reduced at N_3 and N_4. This suggests higher N rates will not be needed to maximize yields and optimize NUE at eCO_2. Results for wheat differed as yields responded to rates greater than N_2 at both aCO_2 and eCO_2, and NUE at the higher N rates under eCO_2 was similar to or greater than N_2–aCO_2. Maintaining nutritional value with eCO_2 yield increases is also critical to food security; these analyses are ongoing.

Organic Reserve Dynamics in Taproots and Rhizomes of Kura Clover vs Alfalfa Following Herbicide Application or Defoliation.

When grown in mulch-cropping maize systems kura clovers endures multiple herbicide applications and mowings to reduce competition to maize. Our objective was to compare organic reserve deposition and reuse in kura clover to conventional and rhizomatous cultivars of alfalfa. Rows were seeding in the field in 2023. In Spring 2024 taproots and rhizomes plants were sampled beginning in March to determine concentrations of sugars, starch, proteins, and amino acids in taproots, and where present, rhizomes. In mid-May three treatments were imposed: defoliation leaving a 5 cm stubble; application of glyphosate herbicide and uncut plants that served as a control. Plants were sampled initially and at ~10-d intervals thereafter, taproots

and rhizomes sampled, and concentrations of organic reserves determined. Laboratory analyses are underway.

5. Published/written work

dos Santos Rocha, M., Brouder, S. M., & Volenec, J. J. (2024) Carbon Dynamics of Kura Clover As a Living Mulch for Maize [Abstract]. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/159257

Volenec, J. J., Nelson, C. J., & Albrecht, K. A. (2024) Dale Smith: A Tribute to the Father of Forage Physiology [Abstract]. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/160371

Lyons, S. E., Arnall, D. B., Ashford-Kornburger, D. L., Brouder, S. M., Christian, E., Dobermann, A., Haefele, S. M., Haegele, J., Helmers, M. J., Jin, V. L., Margenot, A. J., McGrath, J. M., Morgan, K. T., Murrell, T. S., Osmond, D. L., Pelster, D., Slaton, N. A., Vadas, P. A., Venterea, R. T., Volenec, J. J., & Wagner-Riddle, C. (2024) Field Trial Guidelines for Evaluating Enhanced Efficiency Fertilizers [Abstract]. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/157075

Mirbakhsh, M., Brouder, S. M., Volenec, J. J., & DeArmond, N. (2024) Comparing Carbon Sequestration between Perennial and Annual Systems after 10+ Years of Transition [Abstract]. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/159269

Brouder, S.M., and J.J. Volenec. 2024. Systematic review of literature in agriculture and the environment. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. Nov. 10-13. (Abstr.). https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/160372

Ashworth, Amanda J.; Marshall, L.; Volenec, J. J.; Berti, M.; van Santen, E.; Williams, C.; Gopakumar, V.; Foster, J.; Picasso, V.; and Su, J., "Forage Data Hub – A Platform for Sharing Valuable Datasets for Resilience" (2024). IGC Proceedings (1993-2023). 63. https://uknowledge.uky.edu/igc/XXV_IGC_2023/Sustainability/63

Carciochia, W.D., A. Dobermann, N.C. La Menza, S.M. Brouder, C. Donough, D.J. Heuschele, T. Oberthür, P. Sandaña, B.M. Shehu, J.T.S. Pereira, R.P. Soratto, J.J. Volenec, R. Wandri, Y. Wang, S.S. Win, P. He, P. Grassini. 202X. Comparison of potassium internal efficiency, requirement, and removal within and across crop species. XX International Plant Nutrition Colloqium, July 22 to 25, Porto Portugal (in press)

Lyons, S.E., D.B. Arnall, D. Ashford-Kornburger, S.M. Brouder, E. Christian, A. Dobermann, S.M. Haefele, J. Haegele, M.J. Helmers, V.L. Jin, A.J. Margenot, J.M. McGrath, K.T. Morgan, T.S. Murrell, D.L. Osmond, D.E. Pelster, N.A. Slaton, P.A. Vadas, R.T. Venterea, J.J. Volenec, and C. Wagner-Riddle. 2024. Field trial guidelines for evaluating enhanced

efficiency plant nutrition products. Soil Sci. Soc. Amer. J. 2025;89:e20787. http://dx.doi.org/10.1002/saj2.20787

Carciochi, W.D., A. Dobermann, N.C. La Menza, S.M. Brouder, C.R. Donough, D.J. Heuschele, T. Oberthür, P. Snadana, B.M. Shehu, J.T.S. Pereira, R.P. Soratto, J.J. Volenec, R. Wandri, Y. Wang, S.S. Win, P. He, P. Grassini. 2025. Quantifying potassium requirement and removal across crop species. Field Crops Res. 322. 109717. https://doi.org/10.1016/j.fcr.2024.109717.

Johnson II, F.E., A.O. Dada, S.D. Armstrong, D.R. Smith, J.J. Volenec, and S.M. Brouder. 2025. Theoretical ethanol production and soil CO_2 emissions from Midwestern bioenergy systems. BioEnergy Res. 18(1), p.34. https://doi.org/10.1007/s12155-025-10832-0.

Ashworth, A.J., A. Tyson, T. Propst, L. Marshall, C. Li, J.J. Volenec, M.T. Berti, V. Picasso, J.L. Foster, and J. Su. 2025. Knowledge graph applications for identifying resilient forage systems. Agric. Environ. Lett. https://doi.org/10.1002/ael2.70021.

Volenec, J.J. and C.J. Nelson. 202X. Environmental aspects of forage management. Chapter 5. pp. (in press). In: M. Collins, C.J. Nelson. K.J. Moore and D.D. Redfearn (eds.) Forages-An Introduction to Grassland Agriculture. Volume I. 8th Edition. John Wiley & Sons, Inc., New York, NY.

Iowa
Iowa State University (Gruss)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The forage lab at Iowa State University, research focus is on diversification in space (intercropping) ant time (rotations), and grazing impacts on CRP, particularly grassland bird populations.

2. New Facilities and Equipment

Blue Sun Scientific Phoenix 5000 NIR Forage Analyzer

3. Unique Project Related Findings

None

4. Accomplishment Summaries

In 2024 there have been four trials that have been implemented focusing on diversification in space and time. Intercropping with summer annual focuses on maximizing productivity with cover crops and the establishment of alfalfa in space. While alternatives to traditional corn silage, examine the use of forage sorghum and short stature corn as a silage alternative. An additional 2 grazing trials focusing on impacts on CRP and alfalfa grazing tolerance.

Projects started in 2024 (all projects are ongoing)

1. Fall and spring establishment of alfalfa with summer annuals
2. Intercropping summer annuals and cover crops to extend the grazing season
3. Forage sorghum as corn silage in pest areas
4. Short stature corn viability as silage
5. Impacts of grazing on CRP
6. Alfalfa grazing tolerance

5. Impact Statements

Research conducted at Iowa State University in 2024-2025 significantly advances understanding of forage management through diversified cropping strategies and grazing practices. By intercropping alfalfa with summer annuals and cover crops, this work identifies methods to maximize productivity, extend the grazing season, and improve forage establishment. Evaluations of forage sorghum and short stature corn as viable silage alternatives offer producers pest-resilient and potentially more sustainable feed options compared to traditional corn silage. Additionally, investigations into grazing impacts on CRP lands and alfalfa tolerance provide critical insights into how grazing management strategies can influence grassland biodiversity and forage durability, directly supporting ecological goals alongside agricultural productivity.

6. Published Written Works

Refereed publications

Gupta, Varsha, **Shelby M. Gruss,** Davide Cammarano, Sylvia M. Brouder, Peter A. Bermel, Mitchell R. Tuinstra, Margaret W. Gitua, and Rakesh Agrawal. 2024. " Optimizing Corn Agrivoltaic Farming through Farm-scale Experimentation and Modeling." Cell Reports Sustainability 1 (7). https://doi.org/10.1016/j.crsus.2024.100148.

Grubbs, E.K., **S. M. Gruss,** V. Z. Schull, M. J. Gosney, M. V. Mickelbart, S. Brouder, M. W. Gitau, P. Bermel, M. R. Tuinstra, R. Agrawal. 2024. "Optimized Agrivoltaic Tracking for Nearly-Full Commodity Crop and Energy Production." Renewable and Sustainable Energy Reviews 191 (March): 114018. https://doi.org/10.1016/j.rser.2023.114018.

Book Chapters

Moore, Kenneth J. and **Shelby M. Gruss**, "Structure and Morphology of Grasses." Forages, Volume 1. Edition 8. (accepted).

Moore, Kenneth J. and **Shelby M. Gruss,** "Compendium of Common Forages." *Forages, Volume 1*. Edition 8. (accepted).

Outreach and Extension Publication

Owen, Michael D.K., Meaghan Anderson, Wesley Everman, Betsy Danielson, and **Shelby M. Gruss.** 2025. "2025 Herbicide Guide: Iowa Corn and Soybean Production." Iowa State University Extension and Outreach. https://store.extension.iastate.edu/product/12150

Gruss, Shelby M., and Grant Dewell. "Management Strategies of Prussic Acid Toxicity in Sorghum." Iowa State University Extension and Outreach. https://shop.iastate.edu/cropr3199.html

Shelby M. Gruss. 2024 *Contributed to:* "Forage Field Guide." Fourth Edition. *Purdue University Extension-The Education Store.*

7. Scientific Outreach Presentations

Gruss, Shelby M. (2025). Summer Annuals as a Nurse Crop for Spring- & Fall-Planted Alfalfa. Focus on Forage. Midwest Forage Association Annual Meeting. Wisconsin Dells, WI.

Jaschke, Lauren, and **Shelby M. Gruss.** (2024). "Establishing alfalfa with a summer annual nurse crop." AFGC, Kissimmee, FL.

Harle, Courtney, Fernando Miguez, and **Shelby M. Gruss**. (2024). "The big and little of corn silage." AFGC, Kissimmee, FL.

Grubbs, E.K., **S. M. Gruss**, V. Z. Schull, Changkyun Lee, S. Brouder, M. W. Gitau, P. Bermel,

M. R. Tuinstra, R. Agrawal. 2024. Commercially Available Solar Tracking Angle Optimization with Maximal Crop Production for State-Wide Agrivoltaic Potential Assessment. IEEE 52nd Photovoltaic Specialist Conference (PVSC). Seattle, WA.

Scott, B., Cassida, K., **Gruss, S.,** & Bontrager, J. (2024, Nov. 10-13). Nitrogen cycling in biodiverse perennial forage mixtures. ASA, CSSA, SSSA international annual meeting, San Antonio, TX.

Schwab, D. L., Michel, J., Reynolds, B., Pecinovsky, K. T. & **Gruss, S.,** (2024) "Evaluating rotations of winter annual and summer annual forages for yield, nutritional value, and economic sustainability as forage resources for beef cattle in northern Iowa", *Iowa State University Animal Industry Report* 1(1). doi: https://doi.org/10.31274/air.17746

8. Collaborative Grants

S. Gruss, M. Chamas, A. Johnson, and V. Cano Camacho. Enhancing Grazing Management Programming, Education, and Networking in Iowa. USDA-Grazing Land Conservation Initiative. $307,446.
E. Lundy-Woolfolk, **S. Gruss**, and B. Reynolds. Characterizing grazing tolerant alfalfa varieties in Southern Iowa. Iowa Beef Industry Council. $35,118.
Tanner J. Oyen. Graduated May 2025. "Suitability of short-stature corn hybrids in dairy systems."

9. Graduate Students
Indicate name, MS or PhD, graduation date or expected graduation date, thesis title
Harle, Courtney. MS. Graduation Date May 2026. "Alternative silage options compared to traditional corn"
Jaschke, Lauren, MS. Graduation Date Dec. 2026. "Intercropping with summer annuals."

Kentucky
University of Kentucky (McCulley)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The forage research group at the University of Kentucky (UK) conducts research on how symbioses between forage species and microbes affect forage production, nutritive value, secondary plant metabolites, invasive potential, and pasture resilience to climate variability. The forage extension program at UK is productive, well-known and respected for providing sound, timely advice to forage growers in the region. Both the research and extension teams work closely with the co-located USDA-ARS Forage Animal Production Research Unit (FAPRU).

2. New Facilities and Equipment

The USDA-ARS-FAPRU group has received Federal money for a new building on the UK campus, which will house some of the UK forage group and other UK faculty. A location on the UK campus in Lexington has been identified. The design process concluded in early 2024. Initial bids came in over budget, so the project was delayed. However, the documents are set to be out for bid again soon. At present, there is no estimated opening date.

In western Kentucky (UKREC facility), new permanent buildings are being erected to house the UK faculty and staff displaced by the tornado of December 2021. Majority of the new buildings are in active construction or completed. Completion of the entire rebuild is projected for end of 2025.

3. Unique Project Related Findings

Disruptions to functionally important symbionts with global change will negatively impact plant fitness, with broader consequences for species' abundances, distribution, and community composition. Fungal endophytes that live inside plant leaves and roots could potentially mitigate plant heat stress from global warming. Conversely, disruptions of these symbioses could exacerbate the negative impacts of warming. To better understand the consistency and strength of warming-induced changes to fungal endophytes, we examined fungal leaf and root endophytes in three grassland warming experiments in the US ranging from 2 to 25 years and spanning 2000 km, 12°C of mean annual temperature, and 600 mm of precipitation. We found that experimental warming disrupted symbiosis between plants and fungal endophytes. Colonization of plant tissues by septate fungi decreased in response to warming by 90% in plant leaves and 35% in roots. Warming also reduced fungal diversity and changed community composition in plant leaves, but not roots. The strength, but not direction, of warming effects on fungal endophytes varied by up to 75% among warming experiments. Finally, warming decoupled fungal endophytes from host metabolism by decreasing the correlation between endophyte community and host metabolome dissimilarity. These effects were strongest in the shorter-term experiment, suggesting endophyte-host metabolome function may acclimate to warming over decades. Overall, warming-driven disruption of fungal endophyte community

structure and function suggests that this symbiosis may not be a reliable mechanism to promote plant resilience and ameliorate stress responses under global change. **– *Edwards, J.D. et al. 2025. Global Change Biology.***

4. Accomplishment Summaries

During 2024-2025, faculty from University of Kentucky published data from a number of forage variety trials, other on-farm work, and scientific studies and trained numerous undergraduate and graduate students and postdocs. Outreach activities included various trainings throughout the state and participation in numerous national and regional meetings. One student graduated (MS), and several other students were continuing to be mentored and work on their degrees. Forage-related research in the Pyrenees of France continued, and expanded into Spain and Norway, based on funding from the National Science Foundation. A third student intern was advised as part of the AFRI-SAS-CAP grant effort linked to NCCC-31.

5. Impact Statements

"Interactions among nutrients govern the global grassland biomass-precipitation relationship" - Fay et al. 2025. PNAS.

Issue: Understanding how multiple interacting nutrients regulate the global relationship between mean
annual precipitation and aboveground biomass is crucial for forecasting how ecosystem functioning will be altered by ongoing global changes.

Action: We measured aboveground plant biomass production and species diversity in 71 grasslands on six continents representing the global span of grassland MAP, diversity, management, and soils. We fertilized all sites with nitrogen, phosphorus, and potassium with micronutrients in all combinations to identify which nutrients limited biomass at each site.

Impact: The grassland biomass–precipitation relationship became steeper with an increasing number of added nutrients. Increases in steepness corresponded to the form of interaction among added nitrogen
and phosphorus. We found weak evidence that variation in plant species diversity mediated changes in the biomass–precipitation relationship. Multiple nutrient colimitation, particularly by nitrogen and phosphorus, is a defining feature of grassland biomass–precipitation relationships, and crucial to
predicting grassland responses to global change.

"Genome size influences plant growth and biodiversity responses to nutrient fertilization in diverse grassland communities" - Morton et al. 2025. PLOS Biology.

Issue: Experiments comparing diploids with polyploids and in single grassland sites show that nitrogen and/or phosphorus availability influences plant growth and community composition dependent on genome size; specifically, plants with larger genomes grow faster under nutrient enrichments relative to those with smaller genomes. However, it is unknown if these effects are

specific to particular site localities with speciifc plant assemblages, climates, and historical contingencies.

Action: To determine the generality of genome size-dependent growth responses to nitrogen and phosphorus fertilization, we combined genome size and species abundance data from 27 coordinated grassland nutrient addition experiments in the Nutrient Network that occur in the Northern Hemisphere across a range of climates and grassland communities.

Impact: We found that after nitrogen treatment, species with larger genomes generally increased more in cover compared to those with smaller genomes, potentially due to a release from nutrient limitation. Responses were strongest for C_3 grasses and in less seasonal, low precipitation environments, indicating that genome size effects on water-use-efficiency modulates genome size–nutrient interactions. Cumulatively, the data suggest that genome size is informative and improves predictions of species' success in grassland communities.

6. Published Written Works

Refereed publications

McGrail, R.K., J.A. Nelson, R.C. Pearce, and ***R.L. McCulley***. **2025**. Hemp root system architecture and allometric relationships vary between monoecious and dioecious cultivars. Agrosystems, Geosciences & Environment. http://dx.doi.org/10.1002/agg2.70123

Edwards, J.D., M.R. Kazenel, Y. Luo, J.S. Lynn, ***R.L. McCulley***, L. Souza, C.A. Young, J.A. Rudgers, and S.N. Kivlin. **2025**. Warming disrupts plant-fungal endophyte symbiosis more severely in leaves than roots. Global Change Biology. doi.org/10.1111/gcb.70207

Fay, P.A., L.A. Gherardi, L. Yahdjian, P.B. Adler, J.D. Bakker, S. Bharath, E.T. Borer, W.S. Harpole, E. Hersch-Green, T.E. Huxman, A.S. MacDougall, A.C. Risch, E.W. Seabloom, S. Bagchi, I.C. Barrio, L. Biedermann, Y.M. Buckley, M.N. Bugalho, M.C. Caldeira, J.A. Catford, Q. Chen, E.E. Cleland, S.L. Collins, P. Daleo, C.R. Dickman, I. Donohue, M.E. DuPre, N. Eisenhauer, A. Eskelinen, N. Hagenah, Y. Hautier, R.W. Heckman, I.S. Jonsdottir, J. Knops, R. Laugani, J.P. Martina, ***R.L. McCulley***, J.W. Morgan, H.O. Venterink, P.L. Peri, S.A. Power, X. Raynaud, Z. Ren, C. Roscher, M.D. Smith, M. Spohn, C.J. Stevens, M. Tedder, R. Virtanen, G.M. Wardle, G.R. Wheeler. **2025**. Interactions among nutrients govern the global grassland biomass – precipitation relationship. PNAS 122(15)e2410748122. https://doi.org/10.1073/pnas.2410748122

Morton, J.A., C.A. Carnillas, L. Biedermann, E.T. Borer, L.A. Brudvig, Y.M. Buckley, M. Cadotte, I. Donohue, A. Ebeling, N. Eisenhauer, C. Estrada, S. Haider, Y. Hautier, A. Jentsch, H. Martinson, ***R.L. McCulley***, X. Raynaud, C. Roscher, E.W. Seabloom, C.J. Stevens, K. Vesela, A. Wallace, I.J. Leitch†, A.R. Leitch†, and E.I. Hersch-Green†. **2024**. Genome size influences plant growth and biodiversity responses to nutrient fertilization in diverse grassland communities. PLOS Biology.

Chen, X., S. Chen, M.A. Arthur, ***R.L. McCulley***, X. Liu, D. Xiong, C. Xu, Z. Yang, and Y. Yang. **2024**. Primary productivity regulates rhizosphere soil organic carbon: Evidence from a chronosequence of subtropical Chinese fir (*Cunninghamia lanceolata*) plantation. Science of the Total Environment 955: 177082. doi.org/10.1016/j.scitotenv.2024.177082

Proceedings publications

None to report.

Extension Publications

Henning, J., R. Smith, C. Teutsch, J. Lehmkuhler, and M. Arnold. 2025. Interpreting Baleage Fermentation Test Results. AGR-283.

Romano, M., M. Arnold, R. Smith, and K. Lea. 2025. Fescue Toxicosis in Cattle. ID-221.

Teutsch, C., K. Lea, R. Smith, and B. Coleman. 2025. Improving Kentucky Horse Pastures. AGR-281.

Gotsick, E. and R. Smith. 2024. Using a Rising Plate Meter to Measure Pasture Growth: A Practical Guide. AGR-277.

Olson, G., R. Smith, C. Teutsch, J. Henning, and B. Bruening. 2025. 2024 Annual Grass Report: Warm Season and Cool Season (Cereals). PR-861.

Olson, G., R. Smith, T. Phillips, C. Teutsch, and J. Henning. **2024**. 2024 Timothy and Kentucky Bluegrass Report. PR-856.

Olson, G., R. Smith, C. Teutsch, and J. Henning. **2024**. 2024 Red and White Clover and Annual Lespedeza Report. PR-852.

Olson, G., R. Smith, J. Henning, and C. Teutsch. **2025**. 2024 Long-Term Summary of Kentucky Forage Variety Trials. PR-862.

Olson, G., R. Smith, C. Teutsch, J. Henning, and T. Phillips. **2025**. 2024 Cool-Season Grass Grazing Tolerance Report. PR-859.

Olson, G., T. Phillips, R. Smith, C. Teutsch, J. Henning, T. Phillips, and L. Lawrence,. **2024**. 2024 Cool-Season Grass Horse Grazing Tolerance Report. PR-860.

Olson, G., R. Smith, C. Teutsch, and J. Henning. **2025**. 2024 Alfalfa, Red Clover and White Clover Grazing Tolerance Report. PR-858.

Olson, G., R. Smith, C. Teutsch., T. Phillips, and J. Henning **2025**. 2024 Orchardgrass Report. PR-854.

Olson, G., R. Smith, C. Teutsch, and J. Henning. 2024. 2024 Annual and Perennial Ryegrass and Festulolium Report. PR-857.

Olson, G., R. Smith, J. Henning, and C. Teutsch. 2024. 2024 Alfalfa Report. PR-853.

Olson, G., R. Smith, C. Teutsch, T. Phillips, and J. Henning. 2025. 2024 Tall Fescue, Bromegrass, and Meadow Fescue Report. PR-855.

7. Scientific and Outreach Presentations

1) McGrail, R.K., J.A. Nelson, R.C. Pearce, and R.L. McCulley. **2024**. Hemp flowering behavior influences root system architecture. ASA-CSSA-SSSA Annual Meeting, San Antonio, TX.
2) Eaker, J.T., R.K. McGrail, R.C. Pearce, S.T. Lucas, R.L. McCulley, and L. Moe. **2024**. Influence of industrial hemp on soil health parameters in a Kentucky cropping system. ASA-CSSA-SSSA Annual Meeting, San Antonio, TX.

8. Collaborative Grants

Moe, L.A. (PI), S.T. Lucas, R.L. McCulley, R. Pearce, and G. Halich (Co-PIs). "The Hemp Effect: What impact will incorporating hemp into traditional crop rotations have on the provisioning of agroecosystem services?" ***NIFA-AFRI-Foundational,*** 2020 - 2024. **$500,000**

Welch-Devine, M. (PI), J. Thompson, A. Thompson, R.L. McCulley, T. Mote, and B.J. Burke (Co-PIs). "DISES: Co-producing knowledge to sustain pastoral socio-environmental systems: System feedbacks, future scenarios, and adaptive responses." ***NSF-DISES***, 2022-2026. **$1,599,000**

Picasso Risso, V.D. (PI), M. Berti, K. Cassida, A. Finan, D. Hannaway, W. Lamp, and A. Stevens (Co-PIs) with many subcontracts, including one to R.L. McCulley. "Fostering Resilience and Ecosystem Services in Landscapes by Integrating Diverse Perennial Circular Systems (Resilience CAP)" ***NIFA-SAS-CAP***, 2021-2026. **$10M**

McCulley, R.L. (PI). “Plant natural products and symbiotic diversity improve pasture sustainability.” ***USDA-FAPRU-NA Cooperative Agreement***. 2024 – 2028. **$282,350**

Mote, T (PI), M. Welch-Devine, A. Thompson, J. Thompson, B.J. Burke, and R.L. McCulley (Co-PIs). "Transhumance pastoral systems as a dynamic form of adaptive capacity in managing novel climate risks." ***Belmont Forum***. 2023-2026. **$300,000**

9. Graduate students

Reilly Kaplan-Fardy, MS in Integrated Plant & Soil Sciences, graduated **2024**, University of Kentucky.

Kent Pham, PhD in Integrated Plant & Soil Sciences, expected graduation **2025**, title - TBD.

Jack Eaker, MS in Integrated Plant & Soil Sciences, expected graduation **2025**, title - TBD.

Joseph Ray, MS in Integrated Plant & Soil Sciences, expected graduation **2026**, title – TBD.

Jonathan Stephens, MS in Integrated Plant & Soil Sciences, expected graduation **2026**, title – TBD.

Maine
University of Maine (Romero)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The main focus of my research program at the University of Maine is to provide solutions to the issue of PFAS contamination in dairy systems. For that purpose, we are 1) developing a PFAS feed binder; 2) assessing strategies to increase the excretion of PFAS via urine and feces, 3) assessing hay and silage making strategies that can reduce PFAS exposure in cattle.

2. New Facilities and Equipment

- New robotic dairy farm for up to 60 lactating cows.
- John Deere round baler fitter with knives and automatic preservative applicator
- FOSS NIRS DS3 synch with forage consortium database
- Cyclotec grinder with all accessories
- Particle filtration systems for balance and for mixing PFAS boluses made of forage.
- 5 decimal Mettler Toledo balance with antistatic device
- Kuhn baleage wrapper
- Bale grabber
- Ag bagger
- Mini silo bagger
- 4 season RV for remote work
- IDEXX blood cell analyzer and blood metabolite analyzer
- SORVALL 6x250 mL bottle centrifuge at 18,000 g
- 24 metabolic crates for small ruminant work
- 2 CALAN data rangers
- 36 ANKOM gas production bottles
- Agilent positive pressure manifold for PFAS extraction
- N evaporator for PFAS extraction
- Disposable head grinder
- 24 dairy ewes plus 3 rams – East Friesian
- Dodge Caravan van

3. Unique Project Related Findings

PFAS in Dairy Systems Line of Research

PFOS contamination in livestock is a growing concern due to its persistence and accumulation in milk and meat, especially when animals consume contaminated forage or water. Dairy farms dealing with PFOS contamination face significant challenges as milk is a major excretion route for PFOS in lactating animals. We aim to find a safe-to-feed binder that can reduce PFOS contamination in milk and beef using lab techniques simulating

ruminal, abomasal (a.k.a. stomach of ruminants) and duodenal conditions while also expanding our understanding of PFOS ruminal release kinetics from forage substrates.

Objective 1 - This objective was guided by prior findings showing that cholestyramine, an anion exchange resin, can bind up to 52% of PFOS in ruminal fluid via its quaternary ammonium groups and hydrophobic moiety. As a result, we evaluated the relative efficacy of various quaternary ammonium-containing binders (QBDs) to sequester PFOS under simulated ruminal, abomasal, and duodenal conditions. The evaluated binders included cholestyramine - an anion exchange resin (AER), a polymer with quaternary ammonium groups (CPQ), a natural by-product feed (NBF), a polysaccharide with quaternary ammonium groups (PLQ), a clay binder amended with quaternary ammonium groups (CLQ), and a dioctahedral phyllosilicate clay binder (CLY). To simulate rumen conditions, PFAS-contaminated grass (3g) was mixed with 0.05g of each binder before adding 100 mL of rumen media. ANKOM bottles were shaken at 60 rpm, and incubated for 48 h at 39°C. After centrifugation, the rumen fluid was analyzed for PFOS and rumen fermentation analysis and the ruminal pellet was freeze-dried. The percentage of PFOS binding affinity of the respective binders was calculated in relation to CON. A randomized complete block design (RCBD) with a total of 4 blocks was used to analyze the data using SAS v.9.4 PROC GLIMMIX. Differences were declared at $P \leq 0.05$. Fisher's protected least significant difference (LSD) tesy was used for mean separation. Finding revealed that AER exhibited a high ability to sequester PFOS (89.6%), followed by CQQ (31%) and NBF (26.7%) (SEM=7.56, $P<0.01$). All other tested binders had binding capacities below 10%. None of the binders affected ruminal pH, except CPQ (pH=6.59 vs. $\bar{x}$=6.04; SEM = 0.1, $P < 0.01$) which altered in vitro rumen fermentation. CPQ (97.5 mL/g DM vs. $\bar{x}$= 142.3 mL/g DM, SEM = 5.91, $P<0.01$) also altered the asymptotic maximum gas production, while none of the tested binders affected the rate of gas production ($\bar{x}$=7.91 ± 1.08 %/h). Ammonia-N concentrations were not affected by the tested binders ($\bar{x}$=: 32.5 ± 4.22 mg/dL). CPQ (125.5 mM) and PLQ (142.6 mM) significantly reduced total volatile fatty acids (VFA) production ($\bar{x}$=157.08, SEM = 2.15, $P < 0.01$).

To simulate abomasal and duodenal conditions, the Ross protocol (2013)[1] was used. The freeze-dried ruminal pellet resulting from the in vitro ruminal incubation was rinsed with approximately 20 mL of the artificial saliva to remove any unbound PFOS. It was then re-suspended in abomasal solution (Hydrochloric acid and pepsin, pH 2), and incubated for one hour at 39°C followed by one hour in a shaker at the same temperature to simulate abomasal conditions, and finally centrifuged at 8,000 g at 4˚ C for 15 min.
The supernatant was analyzed, and the pellet was rinsed with approximately 20 mL of the artificial abomasal solution and re-centrifuged. Next, the pellet was resuspended in a simulated duodenal solution (24 h at 39˚°C) and subsequently centrifuged to analyze the supernatant and pellets. For each of the abomasal and duodenal steps (Ross, 2013), there will be a natural release of PFOS in the untreated control due to the action of digestive enzymes and pH under such conditions, this might come from the feed or microbial pellet. Consequently, the desorption is expressed as the amount of PFOS desorbed from each binder

[1] Ross, D. A. (2013). Development of an in vitro duodenal digestibility assay for ruminant feeds: a three-step procedure (rumen–pepsin–pancreatin). Cornell University.

by subtracting PFOS naturally released in CON. Data were analyzed using a randomized complete block design (n = 4) in SAS v.9.4, with a significance declared at $P \leq 0.05$. The simulated abomasal desorption varied across the tested binders, ranging from 0.43 ppb of PFOS desorbed in AER to 3.2 ppb of PFOS desorbed in NBF. Others had 2.85, 2.11, 1.85, and 1.53 ppb of PFOS desorbed for CLQ, CPQ, PLQ, and CLY, respectively (P=0.23, SEM = 0.57). Under duodenal conditions, desorption values among the binders showed no differences ($\bar{x}$= |27. 9| ± 39.6 ppb PFOS desorbed [i.e., calculated as the difference between PFOS desorbed from the binder and that from the control] P=0.61) with no PFOS desorbed from any binders compared to the control. Only CPQ had an effect on ammonia-N concentrations (3.24 vs. $\bar{x}$=: 5.32 ± 0.29 mg/dL) compared to other binders (P<0.01). The incubation time had an effect on the pH levels of the tested binders under simulated abomasal (average pH=1.92 at the beginning vs. average pH=2.19 after one hour of incubation; P<0.01) and duodenal conditions (average pH=7.75 at the beginning vs. average pH=7.64 after one hour of incubation; P<0.01). This study demonstrated that the tested binders, particularly AER and NBF, effectively sequestered PFOS without disrupting microbial fermentation or gas production under simulated ruminal conditions. Additionally, there was no significant PFOS desorption from the binder-PFOS complex under simulated abomasal and duodenal conditions.

Alfalfa Hay Line of Research

Effects of an ammonium propionate-based preservative on the nutrient losses, heating kinetics, and microbial counts of high-moisture alfalfa-grass hay round bales

Our objective was to investigate the effects of an ammonium propionate-based commercial preservative on alfalfa-grass hay round bales produced at high moisture concentration (23.71 ± 2.06%). The treatments (TRT) were 1) FRESH CUT® Plus (FC), a commercial mixture of organic acids (incl. propionic and acetic acids) buffered with ammonium hydroxide applied at a 1.2% application rate (fresh basis), and 2) untreated control bales (CON). Twelve large-round bales [244 kg fresh; 1.2 × 1.0 m; 220 kg dry matter (DM)/m^3] were produced following a randomized complete block design (6 blocks) with areas within the field as the blocking factor. The bales were placed on wooden pallets and stored inside a barn for 60 d. Representative core samples were taken at 0, 5, 15, 30, and 60 d of storage (DAYS). Data were analyzed as a 2 TRT × 5 DAYS factorial arrangement with repeated measures using the PROC GLIMMIX procedure of SAS v.9.4. Bale initial DM was used as a covariate. Differences were declared significant at $P < 0.05$. After 60 d storage, no differences in storage DM losses were observed between TRT ($\bar{x}$ = 2.12 ± 1.28%). Across all DAYS, FC had: 1) a lower DM concentration than CON (78.28 vs. 79.61 ± 0.54%); 2) a lower pH than CON (5.27 vs. 5.80 ± 0.10); 3) a lower neutral detergent fiber concentration than CON (58.66 vs. 60.16 ± 0.69% DM basis); and 4) lower mold (5.61 vs. 6.62 ± 0.31 log CFU/g fresh) and yeast counts (3.87 vs. 4.71 ± 0.34 log CFU/g fresh) than the CON. During the d 5 to d 43 of storage, the FC had a lower internal bale temperature than CON (28.06 vs. 40.92 ± 2.93ºC). The maximum bale temperature was lower for FC than the CON (32.38 vs. 43.16 ± 2.33ºC) during weeks 2 to 7 of storage. Similarly, FC had lower heating-degree days (>30°C) than CON during weeks 2, 3, 4, and 6 of storage (26.19 vs. 83.80 ± 17.28ºC). In

conclusion, applying FC minimized the spoilage of alfalfa-grass hay round bales produced at 23.71% moisture by reducing nutrient losses and microbial growth during storage.

Effects of an ammonium propionate-based preservative on the ruminal *in vitro* gas production kinetics of high-moisture alfalfa-grass hay round bales

Our objective was to investigate the effects of an ammonium propionate-based commercial preservative on the ruminal *in vitro* gas production kinetics of alfalfa-grass hay round bales produced at a high moisture concentration (23.71 ± 2.06%). The treatments (TRT) were 1) FRESH CUT® Plus (FC), a commercial mixture of organic acids (incl. propionic and acetic acids) buffered with ammonium hydroxide applied at a 1.2% application rate (fresh basis), and 2) untreated control bales (CON). Twelve large-round bales [244.0 ± 19.7 kg fresh; 1.2 × 1.0 m; 220 ± 20.8 kg dry matter (DM)/m^3] were produced following a randomized complete block design (6 blocks) with areas within the field as the blocking factor. The bales were placed on wooden pallets and stored inside a barn for 60 d. Representative core samples were taken at 0, 5, 15, 30, and 60 d of storage (DAYS). The ruminal *in vitro* gas kinetics were recorded for 48 h using the Ankom RF gas production system. Data were analyzed with a 2 TRT × 5 DAYS factorial arrangement with repeated measures using the PROC GLIMMIX procedure of SAS v.9.4. Differences were declared significant at $P < 0.05$. In the companion abstract, across all DAYS, FC had 1) lower DM and neutral detergent fiber (NDF) concentration, 2) lower microbial counts (i.e., yeast and molds), and 3) lower internal bale temperature than the CON without affecting storage DM losses. At d 15, FC had higher maximum gas production than the CON (150.70 vs. 136.85 ± 5.38 ml/g incubated DM), but no differences were observed at the other DAYS ($\bar{x}$ = 138.2 ± 5.38 ml/g incubated DM). Across all DAYS, no differences between the TRT were observed in 1) rate of gas production ($\bar{x}$ = 5.20 ± 0.17 %/h), 2) lag of gas production ($\bar{x}$ = 0.57 ± 0.15 h), 3) methane ($\bar{x}$ = 12.73 ± 0.59 ml/g degraded DM), 4) *in vitro* true DM digestibility ($\bar{x}$ = 68.32 ± 0.66% DM), 5) *in vitro* NDF digestibility ($\bar{x}$ = 48.47 ± 1.07% NDF). In conclusion, applying FC increased ruminal gas production at d 15 but did not affect other gas production measures, including methane emissions.

Evaluating the responsiveness to propionic acid of high-moisture grass hay across a gradient of alfalfa inclusion

Our objective was to determine the effects of the forage mixture (ALF), dose of propionic acid (DOSE), and storage stage (STG) on high-moisture hay (27.4%). Forage mixtures had 4 levels: 0/100, 35/65, 65/35, and 100/0% of alfalfa/timothy grass. Propionic acid was applied at 0, 0.5, and 1.0% (fresh basis), and STG was d 0 (start) and 61 (end). Data was analyzed as a randomized complete block design (5 field blocks) with a 4 ALF × 3 DOSE × 2 STG factorial arrangement using SAS v.9.4. For heating measures, day was a repeated measure. Mini bales were prepared in this study (weight: $\bar{x}$ = 496.9 g fresh basis). Differences were declared at $P \leq 0.05$. The DM increased from d 0 to 61 (72.6 to 85.6% ± 0.49; STG). After 61-d storage, DM losses were higher for 0 and 0.5% DOSE ($\bar{x}$ = 8.61 ± 1.092%) vs 1.0 (5.18). For all ALF at d 61, as DOSE increased, mold count decreased (7.58,

6.44, and 5.79 ± 0.226 log CFU/g fresh; DOSE x STG). For all STG and DOSE, ALF 1 had a lower mold count than all other levels (5.58 vs $\bar{x}$ = 6.21 ± 0.207 log CFU/g fresh, respectively; ALF). For all ALF at d 61, as DOSE increased, yeast count decreased (5.15, 3.72, and 2.65 ± 0.297 log CFU/g fresh; DOSE x STG). For all DOSE and STG, ALF 100% had lower yeast count compared to 0%, while 35% and 65% were not different (4.35, 5.51, and $\bar{x}$ = 5.04 ± 0.288 log CFU/g fresh, respectively; ALF). For all ALF, DOSE 0 had a higher maximum bale temperature than 0.5 and 1.0 (32.0 vs $\bar{x}$ = 22.3 ± 0.96°C, respectively; DOSE). For all DOSE, on d 2-4 and 8-16, ALF 0% had a higher bale temperature than 100% (Δ=1.61 ± 0.533°C), while on d 50, 51, 53, 57, 58, 60, and 61, ALF 100% had a higher bale temperature than 0% (Δ=1.15 ± 0.533°C). Across all ALF, DOSE 1.0 had a lower bale temperature than 0 from d 1 to d 18 (Δ=2.91 ± 0.462°C), and 1.0 had a lower bale temperature than 0.5 on d 9-18 (Δ=1.17 ± 0.462°C). In conclusion, applying 1.0% propionic acid reduced DM losses, microbial counts, and bale temperatures in high-moisture hay, regardless of alfalfa inclusion. Lower temperatures indicate improved preservation due to less spoilage during storage.

Evaluating the responsiveness to propionic acid of grass hay baled at 80% DM across a gradient of alfalfa inclusion

Our objective was to determine the effects of the forage mixture (ALF), dose of propionic acid (DOSE), and storage stage (STG) on hay preservation. Forage mixtures had 4 levels: 0/100, 35/65, 65/35, and 100/0% of alfalfa/timothy grass. Propionic acid was applied at 0, 0.25, and 0.5% (fresh basis), and STG were d 0 (start) and 40 (end). Data was analyzed as a randomized complete block design (5 field blocks) with a 4 ALF × 3 DOSE × 2 STG factorial arrangement using the PROC GLIMMIX of SAS v.9.4. For heating measures, day was a repeated measure. Mini bales were prepared in this study (Bale weight: $\bar{x}$ = 498.4 ± 5.77 g fresh basis; density: $\bar{x}$ = 275.3 ± 5.9 kg DM/m3). Differences were declared at P ≤ 0.05. The DM increased from d 0 to 40 (79.9 to 82.0 ± 0.21%; STG). After 40-d storage, DM losses were higher for 0% DOSE (4.23% ± 0.454) vs 0.25% and 0.5% ($\bar{x}$ = 1.76). For both STG, at 0.5% DOSE, ALF 65% had higher mold counts than 0 and 100% (5.84 vs. $\bar{x}$ = 5.07 ± 0.204 log CFU/g fresh, respectively), but was no different than ALF 35% (5.34); DOSE 0 ($\bar{x}$ = 6.53 ± 0.204°C) and 0.25 ($\bar{x}$ = 5.86 ± 0.204°C) were not affected by ALF (ALF × DOSE). For all ALF at d 40, as DOSE increased, yeast count decreased (5.15, 4.55, and 4.05 ± 0.136 log CFU/g fresh, respectively; DOSE × STG). For all DOSE at d 40, ALF 100% had the lowest yeast count compared to all other ALF levels (4.0 vs $\bar{x}$ = 4.78 ± 0.151 log CFU/g fresh, respectively; ALF × STG). ALF or DOSE did not affect maximum bale temperature across the 40 d ($\bar{x}$ = 24.2 ± 0.36°C). Across all ALF, DOSE 0.5 had a lower bale temperature than 0 from d 15 to 40 (Δ= 1.38 ± 0.192°C), and 0.5 had a lower bale temperature than 0.25 from d 25 to d 40 (Δ= 0.479 ± 0.192°C). In conclusion, applying 0.5% propionic acid reduced DM losses, yeast counts, and bale temperature in grass hay stored at 80% DM, regardless of the alfalfa inclusion rate. Lower bale temperatures suggest improved preservation and reduced microbial spoilage risk. These results support the use of propionic acid-based preservatives to enhance hay stability when baling DM is around 80%.

Fungal, nutritional, and mycotoxin composition of alfalfa-grass hay mixtures from the northeast and northcentral regions of the United States

Our objective was to assess the fungal, nutritional, and mycotoxin composition of alfalfa-grass hay mixtures from across the northeast and northcentral regions of the US. Sixteen hay samples were taken from Wisconsin (8), Vermont (3), Maine (3), New Jersey (1), and New York (1). Samples were collected from distinct hay lots, following the National Forage Testing Association protocols. Samples were analyzed with near-infrared spectroscopy for nutritional composition measures and with HPLC-MS/MS for mycotoxin analysis. Fungi were isolated and identified to the genus level by morphological characters. DM was 80.8% (77.0 – 85.1, SD= 3.38), pH was 5.75 (5.12 – 7.16, SD= 0.509), and CP was 18.1% DM (11.9 – 23.4, SD= 3.03). The mold count mean was 5.62 log CFU/g fresh (4.17 – 6.72, SD= 0.754) and the yeast count mean was 4.63 log CFU/g fresh (1.5 – 7.16, SD=1.374). Genera identified were *Phoma spp.* (17 strains), *Aspergillus spp.* (15 strains), *Mucor spp.* (7 strains), *Penicillium spp.* (6 strains), *Cladosporium spp.* (5 strains), *Fusarium spp.* (5 strains), and *Coniothyrium spp.* (1 strain). The genera that were most frequently identified included *Aspergillus spp.*, which was detected in all states except Vermont, and *Phoma spp.*, which was present in samples from all states except New Jersey. Mycotoxins were identified and their prevalence was as follows: Vomitoxin (12.5% of the samples, 0.182 – 0.221 ppm, $\bar{x}$ = 0.201, SD= 0.0275), Zearalenone (50%, 31.1 – 414.8 ppb, $\bar{x}$ = 106.7, SD= 126.30), T2 (12.5%, 6.42 – 51.8 ppb, $\bar{x}$ = 29.1, SD= 32.06), Fumonisin B1 (12.5%, 0.116 – 0.419 ppm, $\bar{x}$ = 0.294, SD= 0.1582), and Fumonisin B2 (6.3%, 0.112 ppm). In conclusion, *Aspergillus spp.* and *Phoma spp.* were the most frequently identified genera and Zearalenone was the most common mycotoxin. Among the sampled bales, half of them had a DM below recommendation, according to type, size, and weight.

4. Accomplishment Summaries (limited to projects with direct multi-state involvement)

Not applicable.

5. Impact Statements

We have identified two PFAS feed binders so far: one synthetic and another based on a modified feed ingredient. They sequester PFOS with negligible release under abomasal and intestinal conditions. This will reduce significantly the contamination of milk and meat.

We found that buffered organic acid based on ammonium propionate are as effective as plain propionic acid for high moisture hay. Also, that alfalfa inclusion rate does not affect the effectiveness of propionic acid hay preservative. Also, that a preservative based on ammonium propionate reduces heating peaks in hay reducing the chances of hay fire. Finally, mold species causing spoilage during storage may not be extremely different across northeastern states and Wisconsin.

6. Published Written Works

Refereed publications

Leon-Tinoco AY, Garcia M, Stonoha-Arther C, Brito AF, Romero JJ. Factors Influencing Protein Utilisation in Legume Silage and Hay for Ruminants. Grass and Forage Science. 2025;80(2):e12729. doi: https://doi.org/10.1111/gfs.12729.

Zamudio D, De Castro RA, Jimenez-Lagos AP, Cardoso MVSB, Killerby MA, Pereira G, et al. Effects of wilting extent on the concentration of phytoestrogens, nutritional value, microbial populations, and in vitro ruminal methane emissions of red clover hay and silage across stages. Journal of Dairy Science. 2025. doi: https://doi.org/10.3168/jds.2025-26321.

Zamudio, D., M. A. Killerby, R. C. Charley, E. Chevaux, P. Drouin, R. J. Schmidt, J. Bright, and J. J. Romero. 2024. Factors affecting nutrient losses in hay production. Grass and Forage Science 79(4):499-515.

Killerby, M. A., S. T. R. Almeida, G. M. Oppong, D. Zamudio, C. Knight, L. B. Perkins, C. Wu, S. Annis, and J. J. Romero. 2024. Effect of sodium lignosulfonate and propionic acid application rate on dry matter losses, nutritional composition, in vitro gas production, and fungal populations of high moisture alfalfa hay mini bales. Animal Feed Science and Technology 316:116065.

Proceedings publications None

Bulletins and Extension Factsheets None

Online Resources
Website for our livestock PFAS work
https://umaine.edu/animal-pfas/

7. Scientific and Outreach Presentations *(NCCC31 members bolded)*

Abstracts , symposium and conference presentations

As main presenter:
J.J. Romero, S.A. Annis, A. Brito, J. Alvez, and L. Ferraretto. 2024. A novel approach to expand our understanding of alfalfa hay spoilage and improve the efficacy of hay preservatives. North American Alfalfa Improvement Conference. Washington. USA.

J.J. Romero. The impact of PFAS on the forage-herbivore-human continuum and the optimization of forage preservatives to improve the efficiency of nutrient utilization in livestock systems. 2024. Ecophysiological Aspects of Forage Management. North Dakota. USA.

J.J. Romero. PFAS in Animal Production Systems. 2024. Colby College. Maine. USA.

As corresponding author (lead advisor):

Nishimwe et al. An anionic exchange resin can sequester perfluorooctane sulfonic acid (PFOS) under in vitro ruminal conditions. 2024. American Dairy Science Association Meeting. Florida, USA.

Poblete et al. Assessing the effects of preservative type, dose, and storage phase on nutrient losses, heating kinetics, and microbial populations of high-moisture alfalfa hay. 2024. American Dairy Science Association Meeting. Florida, USA.

Poblete et al. Effects of preservative type and dose on the ruminal in vitro gas production kinetics of high-moisture alfalfa hay. 2024. American Dairy Science Association Meeting. Florida, USA.

Escudero-Alejos et al. Survey on the occurrence of road hay fires in the United States and their economic impact. 2024. American Dairy Science Association Meeting. Florida, USA.

Nishimwe et al. Identification of variables influencing perfluorooctane sulfonic acid (PFOS) serum levels in sheep and cattle through feature selection data mining methods. 2024. American Dairy Science Association Meeting. Florida, USA.

Nowak et al. Identification of variables influencing perfluorooctane sulfonic acid (PFOS) serum levels in rodents through feature selection data mining methods. 2024. American Dairy Science Association Meeting. Florida, USA.

8. Collaborative Grants *(NCCC31 members bolded)*

1. 2025. Evaluating PFAS Bioaccumulation and Depuration in Dairy Sheep and Lambs: Using Insights from Pharmacokinetic Modeling to Develop Mitigation Strategies. G. Pereira (PI), **J.J. Romero (Co-PI)**, K. Nishimwe, S. Lupton. $500,000. Maine DACF.
2. 2025. Enhancing PFAS sequestration by cationic feed binders to decontaminate dairy and beef products in Maine and building UMaine's capacity to evaluate the effects of PFAS on blood metabolites and cell counts in animal studies. **J.J. Romero (PI)**, K. Nishimwe, G. Pereira, and S. Lupton. $250,000. UMaine Cooperative Extension – EPA.
3. 2025. Hay fungal microbiome research. $6,459. **J. J. Romero** (PI). Kemin Industries.
4. 2025. Acquisition of small ruminant pens for PFAS in vivo research. $25,000. **J.J. Romero (PI),** G. Pereira, and K. Nishimwe. Maine Department of Agriculture, Conservation, and Forestry.
5. 2024. Equipment for PFAS livestock research. $700,000. **J.J. Romero (PI)**, S. Lupton, G. Pereira, K. Nishimwe, J. Lemos. 2024. USDA NACA – UMaine PFAS center of excellence.
6. Developing integrated mitigation strategies to help farmers reduce PFAS risks in forage and livestock systems. Mallory, E. (PI), **J.J. Romero** (Co-PI; Sub-award: $600,718), G. Pereira, J. MacRae, and K. Nishimwe. $1,600,000. EPA.
7. 2024. Evaluating the capacity of adsorbents to bind perfluorooctanesulfonic acid (PFOS) across simulated ruminal, abomasal, and intestinal conditions and expanding our understanding of PFOS ruminal release. **J.J. Romero** (PI), Y. Jiang, G. Pereira, and K. Nishimwe. $300,000. USDA-NIFA- Animal Nutrition, Growth, and Lactation Program.

8. 2024. Assessing the capacity of organic adsorbents to bind perfluorooctanesulfonic acid (PFOS) across simulated cattle gastrointestinal conditions. **J.J Romero** (PI), G. Pereira, and K. Nishimwe. $33,300. Maine Organic Farmers and Gardeners Association.

9. Graduate students
Indicate name, MS or PhD, graduation date or expected graduation date, thesis title

- Joe Poblete (PhD, expected May 2026)
- Ana Jimenez (PhD, expected May 2028)
- Barbara Escudero (MSc, expected August 2025)
- Marleth Temporal (MSc, expected May 2027)
- Kailey Kuhlman (MSc, expected August 2027)
- Marco Chusho (MSc, expected December 2027)

Maryland
University of Maryland (Lamp)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

Agricultural insect pest management has focused on the injury and management of insect pests. With the current biodiversity crisis affecting both declining numbers of insects and extinction of species, farm management may be useful to improve the survival of beneficial species of insects. The beneficial biodiversity on farms, such as predators of insect pests, depends on the presence and locations of suitable habitats for their survival and reproduction. Predatory ground beetles, dragonflies, and parasitic wasps are examples of those beneficial species we have sought to improve their populations on farms. Our studies within forage crops and the surrounding farm landscape are designed to better understand the role and value of beneficial insects in the agricultural landscape.

2. New Facilities and Equipment

None

3. Unique Project Related Findings

We discovered that predatory and parasitic insects are more abundant on a less intensively managed farm. Landscape elements contribute to community composition. We also found that predatory dragonflies reproduce in farm ponds, including species that are active in pastures with cattle. In comparing the role of a parasitic wasp on aphids in susceptible and leafhopper-resistant cultivars, we found no evidence that wasps are impeded by the presence of glandular trichomes on resistant alfalfa. Finally, we are testing the potential to use black soldier fly larvae as a substitute protein source for dairy cattle for greater sustainability over the use of soybean meal. To date we found no difference between the use of insect versus soybean meal in the quantity and quality of milk production.

4. Accomplishment Summaries

Craig, H., J. Kraemer, S. Windsor, and W. Lamp. Monitoring on-farm ecosystem services with aerial arthropods – linking taxonomic structure and ecological function. Insects provide various ecosystem services necessary for successful farming, including provisioning, regulating, supporting, and cultural services, and there is a need to monitor the insect biodiversity on farms to adequately determine the contribution of biodiversity to farm health. This study involves describing a protocol for sampling airborne insects to determine the community of insects at the farm-scape level. The goal of this sampling is to assess and compare the health of farms within a citizen-science project. 8x10 inch sticky traps were deployed during the growing season at two University of Maryland farms. Ten traps per farm were set out for a week at a time at five locations varying in type of surrounding vegetation. We selected 95 insect groups (90 families, 5 non-family insect taxa) to count based on size, behavior, and ease of processing and established a database of family characteristics to categorize these groups. From the database, we analyzed characteristics of possible biomonitoring parameters towards the development of a biotic index at the farm level. Preliminary results indicate that parasitoid and predator abundance is significantly

greater on the less intensively managed farm sampled (Pairwise t-test, $p < 0.001$ for each), and PERMANOVA found significant contributions of landscape components towards overall community composition ($p < 0.05$ for corn, soy, and wooded areas). We intend to compare these indices across sets of farms that vary in the presence of plant diversity, crop perennially, and circular economic systems.

Brucchieri, A., and W. Lamp. Characteristics of farm ponds that promote dragonfly reproduction for conservation biological control. Dragonflies (Insecta: Odonata) are voracious insects that have dynamic relationships within their ecosystems due to their predatory lifestyle as aquatic nymphs and terrestrial adults. They are well documented bioindicators, as nymphs and adults. However, limited research has been conducted on their role as biological control agents in agricultural systems. Many species are dependent on lentic water systems for reproduction and in an altered landscape such as agricultural systems this could pose a problem. Farm ponds may support dragonfly nymphs that emerge as adults and subsequently provide biological control services in agricultural systems such as pastures. To better understand how farm ponds can support dragonflies as biological control agents, we investigated farm pond characteristics that promote dragonfly reproduction, identified species of dragonflies that forage within or above agricultural fields and ponds and investigated dragonfly species that overlap the two habitats. We found that farm ponds supported 19 different species across 16 genera despite variation in water quality, vegetation cover, fish presence and macroinvertebrate community structure. There was an overlap of 14 dragonfly species that were able to successfully utilize farm ponds for reproduction and active cattle pastures as foraging sites. The dominant behavior over ponds was territorial displays and mating while the most common behavior over cattle was foraging. The results give a glimpse into how farm ponds of various features and under different management strategies can provide habitat for dragonfly species that act as biological control agents in livestock pastures.

Salerno, R., and W. Lamp. Ecological intensification within forage systems benefits soil arthropods and soil biota-mediated ecosystem services. Modern agricultural practices, such as intensive soil tillage, crop monocultures, and overfertilization pose sustainability challenges in forage and livestock farming, impacting soil quality and ecosystem stability. Throughout the world, studies have revealed that agricultural intensification negatively impacts aboveground arthropods, prompting interest in ecologically intensified forage systems for agricultural sustainability. Belowground, soil arthropods provide many essential ecosystem services on the farm, including decomposition, biological control, and bioturbation; however, these organisms and their services are generally overlooked. Understanding the response of soil arthropods and soil properties to changes in land use/agricultural management practices is vital for ecologically and economically balanced systems. To investigate how land use in forage systems influences soil arthropod communities, soil properties, and their ecosystem services, I sampled soil biotic and abiotic properties and measured the rate of feeding activity by soil biota. This study was conducted across a land use gradient ranging from intensively managed to semi-natural habitats, including established corn-soybean rotations, forage pastures, grass margins, and woodlots. I found significant differences in several soil properties including soil bulk density and soil moisture between land use types. Soil arthropod communities were more abundant and diverse in pastures compared to corn plots and the soil biological quality was significantly lower in corn

plots compared to all other land uses. Soil taxa such as Acari, Collembola, Diplopoda, and Chilopoda were associated with soil properties investigated here and soil biota feeding activity was highest in ecologically intensified land use types (characterized by high plant diversity, plant perenniality, and system circularity). The results of this study suggest that ecological intensification, through the presence of plant diversity, perenniality, and system circularity, supports soil quality and soil arthropod communities within forage systems. This research informs decision-making in livestock systems as they continue to dominate land use throughout the United States.

Craig, H., A. Tiwari, A. Catañeda, R. Kohn, D. Pitta, E. Rico, and W. Lamp. Black soldier fly larvae (*Hermetia illucens*) as a sustainable methane-mitigating protein supplement for dairy cattle. As the global human population rapidly increases and climate change intensifies, the demand for climate-friendly food becomes more pressing. As it is, the USDA estimates that there were 1.3 billion food insecure people in 2022. The need to increase agricultural productivity has at times compromised the health of our environment in the form of increased greenhouse gas emissions and agricultural intensification. Additionally, in many cases, humans are competing with livestock for food (i.e., corn, soy, wheat, and other grain crops that could be used for human consumption). Furthermore, there is a growing positive feedback loop between climate and livestock feed production; while climate change and its various effects have posed a significant threat to soybean, a staple in livestock feed, enteric fermentation only worsens climate change with methane emissions. The goal of this project was to determine the viability of black soldier fly larvae as a methane mitigating protein substitute in dairy cattle in terms of animal and environmental health. We recruited 14 multiparous, lactating dairy cows in a crossover design over 8 weeks 2 weeks for training, 2 weeks for period 1, 2 weeks for a washout, and 2 weeks for period 2. Manure, gas, rumen fluid, blood, and milk samples were taken at the beginning and end of each period, dry matter intake and milk production was tracked throughout the study. The treatment diet contained approximately 55% corn silage, 10% hay, 20% corn grain, 7.5% soybean meal, 2.5% BSFL meal, 2% mineral mix, 1% vitamin mix, and 1-2% other additives. The control diet will be identical except for 10% soybean meal and 0% BSFL meal. We have yet to analyze the manure, gas, blood, rumen fluid, and volatile fatty acid samples, however, the results to date are as follows. Using a mixed effects model with treatment diet and a baseline-adjusting covariate as the fixed effects and individual cow and period as random effects, ANOVA revealed no significant differences ($P > 0.05$) for somatic cell count; milk urea nitrogen; fat yield and fat percent; protein yield and protein percent; or lactose. Additionally, no significant differences were detected in milk production (Fig. 1). More investigation into these data is required for a full understanding of black soldier fly larvae as a feed alternative in dairy cattle.

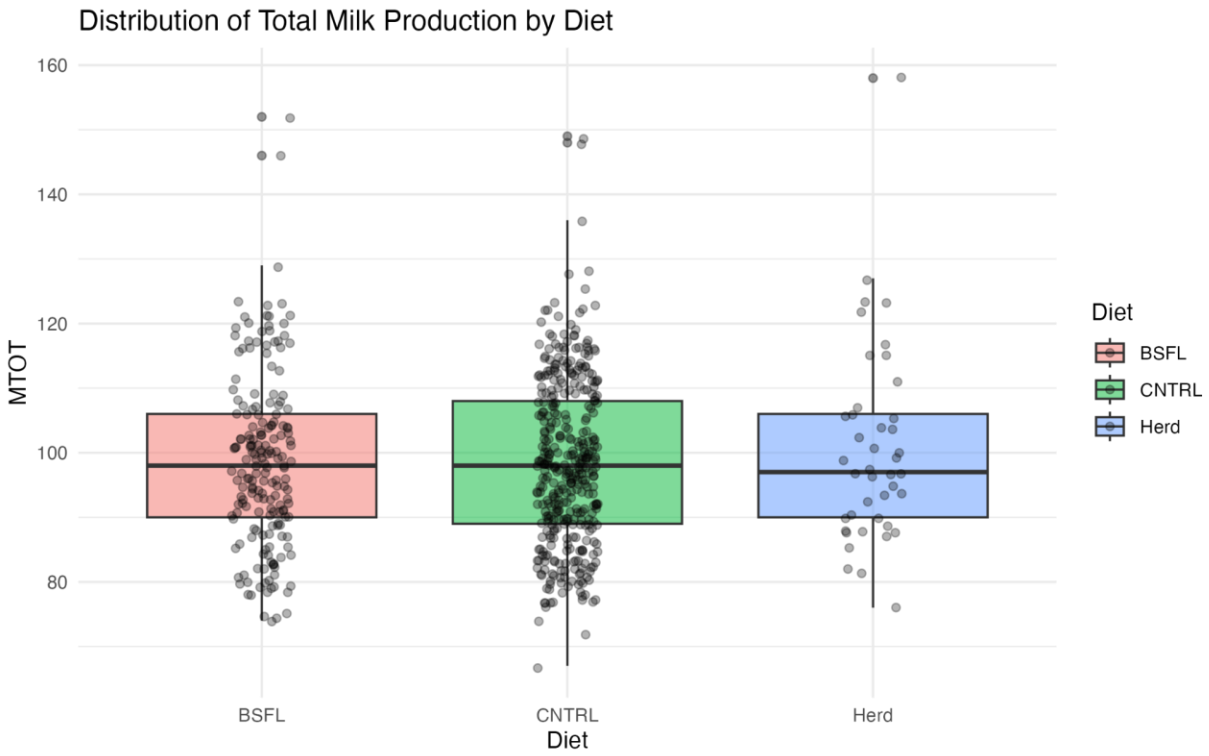

Fig. 1. BoxPlot distribution of total milk production (MTOT) by diet. (BSFL = black soldier fly larvae diet, CNTRL = control diet matched for nutritional value to the herd diet, Herd = diet cows were fed prior to initiation of experimental periods).

Helbling, Y., and W. Lamp. Do glandular trichomes indirectly foster aphid populations in alfalfa by suppressing biological control? Host-plant resistance in alfalfa (*Medicago sativa)* has warded off the potato leafhopper (*Empoasca fabae*) as a primary pest, while allowing secondary pests, such as the pea aphid (*Acyrthosiphon pisum*), to thrive. This study investigates whether glandular trichomes, the basis for host-plant resistance against potato leafhopper, decreases the efficiency of conservation biological control of *A. pisum* by diminishing their primary natural enemy, the parasitoid wasp *Aphidius ervi*. I hypothesized that the resistant *M. sativa* cultivar hosts more *A. pisum* because of reduced biological control by *A. ervi* due to the presence of glandular trichomes. The study system consisted of a resistant *M. sativa* cultivar (Pioneer 55H96), a susceptible *M. sativa* cultivar (Pioneer 55V50), *A. pisum*, and *A. ervi*.

No-choice tests conducted in a growth chamber measuring pea aphid nymph survival, showed that pea aphid nymphs survive equally well on both cultivars ($p = 0.86$). Choice tests conducted in a growth chamber revealed that pea aphids do not express a cultivar preference ($p = 0.31$). Stem samples collected from the field in two consecutive years revealed that parasitoids were not impeded by the presence of glandular trichomes. Mean mummies per stem were not significantly different between the two cultivars in 2023 ($p = 0.33$), and there were more mummies in the resistant cultivar plots in 2024 ($p = 0.01$). This data suggests that the glandular trichomes of resistant alfalfa cultivars do not impede the activity of parasitoids, and therefore the

increase in secondary pest populations in systems using host-plant resistance cannot be attributed to a decrease in biological control.

5. Impact Statements

Integrated Pest Management (IPM) of crops depends on naturally-occurring predators and parasitoids to reduce pest populations as they develop in crops. Pest population suppression by biological control can often replace the need for pesticide use. The reduction of pesticide use not only helps the farmer to reduce his/her costs, but it also protects the biodiversity on the farm that provides many valuable ecosystem services for the farmer as well as the public at large.

Our studies on conservation biological control broaden our understanding of beneficial insects in forage crops as well as nearby habitats such as water sources and drainage ditches. Subtle changes in the management of these crops and habitats may lead to increased levels of biological control and reduce losses by insect pests.

6. Published Written Works

Refereed publications

Windsor, S. D., Shokoohi, A., Salerno, R., & Lamp, W. (2025). Family-Level Diversity of Hymenopteran Parasitoid Communities in Agricultural Drainage Ditches and Implications for Biological Control. Insects, 16(3), 246. https://doi.org/10.3390/insects16030246

Extension publications

Craig, H., Salerno, R.* May 9, 2025. Pesticides and Agriculture Coexisting with Protected Species: The rules, regulations, and conversations that make it work. University of Maryland, Department of Entomology Blog. https://entomology.umd.edu/news/seminar-blog-pesticides-and-agriculture-coexisting-with-protected-species-the-rules-regulations-and-conversations-that-make-it-work

Craig, H., Rogalski, L., Lenahan, M., Hensley, M., Lamp, W. April 19, 2025. Pack a Bug in your Lunchbox: Education on Insects as Food and Feed. American Entomologist, Volume 71, Issue 1, Pages 26-29, https://doi.org/10.1093/ae/tmaf007

Helbling, Y., and W. Lamp. 2025. Abundance of Pea Aphids and Parasitic Wasps in Alfalfa Plots With and Without Glandular Trichomes. Roots in Research Newsletter 2025: 7-9.

7. Scientific and Outreach Presentations

Craig, H., Tiwari, A., Kohn, R., Rico, E., Lamp, W. June 24, 2025. In vitro and in situ evaluations of black soldier fly larvae as a methane-mitigating protein substitute in dairy cattle diets. Ruminant Nutrition Platform Session: Alternative Feed Ingredients for Dairy Rations. American Dairy Science Association Annual Meeting. Louisville, KY.

Craig, H., Tiwari, A., Kohn, R., Rico, E., Lamp, W. March 17, 2025. Evaluating black soldier fly larvae meal as a climate mitigating protein supplement for dairy cattle. Insects as Food and Feed: Promises, Issues, and Opportunities Symposium. Eastern Branch Entomological Society of America Conference. Harrisburg, PA.

Craig, H., and Lamp, W. (co-organizers). March 17, 2025. Insects as Insects as Food and Feed: Promises, Issues, and Opportunities. [Symposium]. Eastern Branch Entomological Society of America Conference. Harrisburg, PA.

Craig, H., February 26, 2025. Bugs and Cows: How insect protein could lead to more sustainable agriculture. Fresh Faces Seminar. University of Pennsylvania. Kennett Square, PA.

Craig, H., Lamp, W. November 12, 2024. Educating and empowering undergraduate students on the importance of insect ecosystem services using interactive displays. Entomological Society of America Annual Meeting. Phoenix, AZ.

Craig, H. Kohn, R., Rico, E., Lamp, W. November 10, 2024. Evaluating Insect Feed as a Climate Mitigating Protein Supplement for Dairy Cattle Three Minute Thesis. Entomological Society of America Annual Meeting. Phoenix, AZ.

Craig, H., Tiwari, A., Kohn, R., Rico, E., Lamp, W. September 20, 2024. Black Soldier Fly Larvae (*Hermetia illucens*) as a Climate Mitigating Protein Supplement: Preliminary Data. Department of Entomology Annual Retreat. University of Maryland, MD.

Craig, H., Lamp, W. February 12, 2024. Insects as Feed for Dairy Cattle?. Undergraduate Guest Lecture to BSCI145 "Insect Apocalypse; real or imagined" course. University of Maryland, MD.

Helbling, Y., Lamp, W. 2024. Does Host-Plant Resistance Inadvertently Increase Secondary Pest Populations by Reducing Biocontrol?. Entomological Society of America Annual Meeting, Phoenix, AZ.

Helbling, Y., Lamp, W. 2025. Do glandular trichomes indirectly foster aphid outbreaks in alfalfa by suppressing biological control?. Entomological Society of America Eastern Branch Meeting, Harrisburg, PA.

Windsor S., Salerno, R., Shokoohi, A., and Lamp, W. 2024. Hymenopteran parasitoid communities in agricultural drainage ditches: Community composition and comparison between crop and non-crop vegetation. Entomological Society of America National Meeting, Phoenix, AZ.

8. Collaborative Grants

Craig, Helen, and William Lamp. University of Maryland Sustainability Fund, 2023-2025, "Incorporating Students in the Evaluation of Insect Feed as a Viable Methane Mitigating Supplement for the UMD Dairy", $44,906

Lamp, W., E. Rico, and D. Johnson. Maryland Agricultural Experiment Station Competitive Grant, 2024-2025, Maryland Agricultural Experiment Station, "Evaluating Insect Feed as a Climate Mitigating Protein Supplement for Dairy Cattle", $30,000.

9. Graduate students

Brucchieri, Amanda, MS, May-2025, "Use of farm ponds to promote dragonfly reproduction for conservation biological control"

Salerno, Robert, MS, May-2025, “Response of soil arthropod diversity and their ecosystem services to ecological intensification of agricultural cropping systems”

Craig, Helen, PhD, May-2027, “Evaluating insect feed as a climate mitigating protein supplement for dairy cattle”

Michigan
Michigan State University (Cassida)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

None

2. New Facilities and Equipment

None

3. Unique Project Related Findings

None

4. Accomplishment Summaries *(limited to projects with direct multi-state involvement)*

Fostering resilience and ecosystem services in landscapes by integrating diverse perennial circular systems. Michigan has four roles in this project: 1) Farm Network-lead development of a nationwide farmer network, 2) Extension - lead development of a nationwide Extension effort, 3) Collaborative Research - participate in a multi-state network of field experiments evaluating soil improvement by resilient cropping practices, and 4) Education - participate in educational activities. *Key Outcomes and other accomplishments realized*: In 2025 we oversaw collection of data from a network of 82 farmers nationwide, including 12 in Michigan. We maintained a website for the project, initiated a Facebook group, and planned other Extension assessments and outputs including a bulletin/video series. Two MS graduate students collected second year field data (biomass, soil, forage quality) from two leveraged collaborative experiments: 1) intercropping corn and alfalfa and 2) nitrogen fixation in alfalfa-grass mixtures. Resilience principles were incorporated into presentations for FFA students, STEM teachers, MSU Extension programming, and an undergraduate forage class.

5. Impact Statements

None

6. Published Written Works *(Cite them with CSSA, ASA references format)*

Refereed publications

1. Baisley, P., and K.A. Cassida. 2025. Overview of autotoxicity in alfalfa (Medicago sativa): Identifying gaps between laboratory findings and demonstration at field scale. *Grassland Science*. http://doi.org/10.1002/glr2.70012.

2. Kaur, H., M. Chilvers, K. Cassida, and M.P. Singh, 2025. Tar spot impacts silage corn yield and forage nutritive value. *Crop, Forage, and Turfgrass Management* 2025;11:e70031, http://dx.doi.org/10.1002/cft2.70031

3. Kaur, H., C. Difonzo, M. Chilvers, K. Cassida, and M. Singh. 2024. Planting time and seeding rate impact insect feeding, ear rots, and forage quality in silage corn. *Agronomy J.* 116:1978-1990. http://doi.org/10.1002/agj2.21620,

4. Cassida, K.A., and H. Collins. 2024. USDA LTAR Common Experiment measurement: Obtaining quality metrics in forage aboveground biomass. Online 8/9/24. https://dx.doi.org/10.17504/protocols.io.n2bvjn6wpgk5/v1

5. Robertson, G.P, B. Wilke, T. Ulbrich, N. Haddad, S.K. Hamilton, D.G. Baas, J. Blesh, T.J. Boring, L. Campbell, K.A. Cassida, J. Doll, T. Guo, M. Hasenick, S. Marquart-Pyatt, M.P. Singh, and J. Stegink. 2024. The Kellogg Biological Station Long-Term Agroecosystem Research Site (KBS LTAR). *J. Envir. Qual.* http://doi.org/10.1002/jeq2.20638

Proceedings publications

None

Bulletins and Extension Factsheets

1. Burns, E, Hill, E., and K. Cassida. (2025.) *Hoary Alyssum, Small But Hazardous to Horses*. MSUE Bulletin (E-3496). Michigan State Univ., East Lansing, MI. Online 5/29/25 https://www.canr.msu.edu/resources/hoary-alyssum-small-but-hazardous-to-horses

2. Cassida, K., J. Paling, J. Dedecker, & C. Kapp. 2025. *2024 Michigan Forage Variety Test Report.* MSU Forage Factsheet 25-01, 27 pages. https://forage.msu.edu/wp-content/uploads/2025/06/2024-Michigan-Forage-Variety-For_Bulletin_2025_Web_Version.pdf/

Articles in Trade Publications

1. Cassida, K.A. 2025. **Forage Research Update: Gleaning the Big Picture from Forage Variety Testing**. *Michigan Hay & Grazier*, Michigan Forage Council, East Lansing, MI. Summer 2025. (circulation ~75) (IN PRESS)

2. Cassida, K.A. 2025. **Forage Research Update: MSU Participates in Development of New Forage Grass Maturity Group Index.** *Michigan Hay & Grazier*, Michigan Forage Council, East Lansing, MI. Spring 2025 pp. 4-5. (circulation ~75)

3. Cassida, K., J. Paling, J. Dedecker, and C. Kapp. 2025. 2024 Michigan Forage Variety Test Report. *Michigan Farm News*, Jan. 30, 2025, pp 18-23. (Circulation ~217,000)

Online Resources

1. Cassida, K.A., and S. Gruss (webmasters). 2023. Ag-Resilience CAP. Website. https://ag-resilience.org/

2. Cassida, K.A. Ag Resilience. Online 2024. Facebook group. https://www.facebook.com/groups/989304282540018

3. Cassida and all MSUE Specialists. Hot Topics. *MSU Extension Virtual Breakfast.* Online Aug 28, 2025. URL pending (WEBINAR/PODCAST)

4. Cassida, KA. Potassium! Why It Matters to Alfalfa Persistence. *MSU Extension Virtual Breakfast*. Online Aug 21, 2025. URL pending (WEBINAR/PODCAST)

5. Cassida and all MSUE Specialists. Hot Topics. *MSU Extension Virtual Breakfast.* Online July 10, 2025. URL pending (WEBINAR/PODCAST)

6. Cassida, KA. Optimizing Forage Quality in Hay and Haylage. *MSU Extension Virtual Breakfast*, online May 1, 2025. https://www.youtube.com/watch?v=Co5LbY35_K4 (WEBINAR/PODCAST, 213 live participants, 631 web views)

7. Kaatz, P., and K. Cassida. 2025. Optimizing Forage Quality is Topic for May 1 Virtual Breakfast Series. *MSU Ag News*. Online 4/23/25 https://www.canr.msu.edu/news/optimizing-forage-quality-field-crops-virtual-breakfast (Article with imbedded YouTube, 681 views)

8. Cassida, KA. Pasture Management for Sheep and Goats. *Sheep & Goats for Small Farms Conference*, Online Mar 8, 2025. URL https://mediaspace.msu.edu/media/2025+Small+Ruminants+for+Small+Farms+Program/1_j9cy900b (WEBINAR, 267 participants)

9. Cassida, K. & S. Newell. Harvest Timing Drives Persistence for Alfalfa. *MSU Extension Field Crops Webinar*. Feb. 24, 2025. URL online 6/30/25 https://mediaspace.msu.edu/media/Field+Crops+Webinar+02-25-25%3A+Alfalfa+Harvest+Considerations/1_gbb2avth (WEBINAR, 140 registered, 85 live participants)

7. Scientific and Outreach Presentations

Abstracts , symposium and conference presentations

1. Baisley, P., Cassida, K. (2024) Interactions between alfalfa autotoxicity and the soil microbiome. ASA – CSSA – SSSA International Annual Meeting, San Antonio, TX. Nov. 10 – 13, 2024. Poster.

2. Scott, B., Cassida, K., Gruss, S., & Bontrager, J. (2024). Nitrogen cycling in biodiverse perennial forage mixtures. ASA, CSSA, SSSA international annual meeting, San Antonio, TX. Nov. 10 –13, 2024. Poster.

3. Hernandez, A., C. Bloomingdale, K. Cassida, L.E. Hanson, and J.F. Willbur. 2024. Cultural management strategies for *Cercospora* leaf spot on sugarbeet. Amer. Phytopathological Soc., Plant Health Conf. July 27-30, 2024. Memphis TN. (poster)

Outreach and Extension presentations

1. Cassida, K.A. Mar. 19, 2025. Maximizing Hay Forage Quality. *Knutson Equipment Forage Harvester Conference*, East Lansing, MI. (38 participants).

2. Cassida, K.A. Mar. 6, 2025. MSU Forage Research Update. *Great Lakes Forage & Grazing Conference*, St. Johns, MI. (89 participants)

3. Beem, G, and K.A. Cassida, K.A. Mar. 5, 2025. Soil Health Demonstration. PSM FFA Open House. East Lansing, MI. (30 participants)

4. Cassida, K.A. Feb. 20, 2025. MSU Forage Research Update. Online presentation. *MSU Extension Crop & Pest Management Update*. Hillsdale, MI. Synchronous Zoom. (15 participants)

5. Cassida, K.A. Feb. 17, 2025. Pest Management in Forages. *Branch County Farmers Day*, Coldwater, MI. Synchronous Zoom. (52 Participants)

6. Cassida, K.A. Feb. 11, 2025. Pest Management in Forages. *MSU Extension Crop & Pest Management Update*. Alpena, MI. Synchronous Zoom. (~30 Participants)

7. Cassida, K.A. Feb. 7, 2025. *MSU Extension Crop & Pest Management Update*. Saginaw, MI. (~80 Participants)

8. Cassida, K.A. Jan. 10, 2025. MSU Alfalfa Research Update. *MSU Extension Crop & Pest Management Update*. Bad Axe, MI. (85 participants)

9. Cassida, K.A. Jan. 6, 2025. Simple methods to improve your pastures. *Michigan Shepherds Weekend*, Lansing, MI. (40 participants)

8. Collaborative Grants *(NCCC31 members bolded)*

New

None

Ongoing

1. Picasso, V., M. Berti, K. Cassida, A. Finan, **D. Hannaway, W. Lamp**, and A. Stevens. 2021-2026. Fostering resilience and ecosystem services in landscapes by integrating diverse perennial circular systems. USDA-NIFA-SAS, $898,527. FUNDED.

2. Cassida, K, and **S. Gruss**. 2023-2025. Nitrogen cycling in biodiverse perennial forage mixtures. Project GREEEN, $98,176.

9. Graduate students
Indicate name, MS or PhD, graduation date or expected graduation date, thesis title

- Ethan Weinrich (MS, Crop and Soil Science, graduated December 2024). Thesis: Weinrich, E. 2024. Plant diversity as a lever for integrated nutrient management and soil biodiversity in agroecosystems. 79 pp. ProQuest Dissertations Publishing, Ann Arbor, MI.
- Jasmine Bontrager (MS, Crop and Soil Science, graduation expected May 2025)
- Brandon Scott (MS, Crop and Soil Science, graduation expected May 2025)
- Rabin Kc (PhD, Crop and Soil Science, graduation expected December 2025)
- Paige Baisley (PhD, Crop and Soil Science, graduation expected December 2026)

North Dakota
North Dakota State University (Berti)
NCCC-31 Ecophysiological Aspects of Forage Management

1. **Impact Nugget:**
Forages research in North Dakota has its main focus in alfalfa production management and intercropping of forage sorghum, sunflower, and corn with alfalfa. Integration of forages research into annual cropping systems increases the delivery of ecosystem services, enhancing resilience and stability.

2. New Facilities and Equipment:
New NIR instrument DS3-F, FOSS for forage quality analysis

3. Unique Project Related Findings:

4. Accomplishments summaries:

Objective 1. Forage management and production research
This project's research has focused on increasing forage yield and forage nutritive value in alfalfa and other forages and forages mixes by optimizing management practices. In 2024, the corn-alfalfa intercropping experiments established in 2022 and 2023 were harvested, showing forage yield was the same in all treatments. We could not distinguish plots established in intercropping with corn and those established alone in the second production year. Optimizing this specific cropping system for growers in the northern Great Plains could increase profitability as well as forage nutritive value and crop efficiency. Since alfalfa established in intercropping with corn was a promising system we evaluated alfalfa-established in intercropping with sunflower, forage sorghum (FS), and sainfoin in four different studies each planted at two locations in 2023 and 2024. Results indicated that sunflower does not decrease in yield when alfalfa or sainfoin is intercropped into it. ***With this research we proved the hypothesis that alfalfa in intercropping with sunflower or sorghum fixes 20-30% more nitrogen than alfalfa alone and that about that same amount is transferred to sunflower. No one else has reported this.***

Intercropping treatments did not have significant impact on forage sorghum biomass yield. Overall high presence of beneficial insects in the plots intercropped with alfalfa supports how alfalfa improves biodiversity. Additionally, the project assessed the economic implications and practical considerations for farmers adopting this intercropping approach.

Objective 2. Bioenergy crops and environmental impact
Testing FS and sorghum x sudan (SS) varieties continues being a key objective of my project. FS is the highest biomass yielding crop in ND and the one with the most potential as feedstock for bioenergy. In 2024, 25 FS, SS, photoperiod sensitive (PS) sorghums, FS types, and double purpose (DP) were tested. In 2024, forage yield ranged between 4.5 and 9.15 tons/acre. The highest yields were obtained with PS hybrids. Forage nutritive value was adequate to feed a 2000 lbs beef cow for most sorghums; average crude protein ranged between 7.87-13.68 and total digestible nutrients average ranged between 40.9 and 54.9% This is part of a project aimed

to select FS lines adapted to northern climates and cold soils.

Two new projects in spring and winter camelina for sustainable aviation fuel (SAF) were conducted in 2024. A second study was conducted to determine the carbon intensity (CI) of three cultivars of spring camelina production with increasing nitrogen rates. Carbon intensity is the amount of CO_2 equivalent/ kg or MJ released to the atmosphere during the crop production phase "cradle to gate". Nitrogen fertilizer has a high CI both through its manufacturing and through field losses as nitrous oxide, increasing CI of camelina products as N rates are increased. Spring and winter camelina maximum seed yield was 1521 kg ha^{-1} and 1410 kg ha^{-1}, at 80 kg N ha^{-1} and 55 kg N ha^{-1}, respectively. The minimum CI for spring camelina and winter camelina was 33.6 and 21.5 g CO_2 equivalent (CO_{2e}) MJ^{-1}, at N rates of 34 and 32 kg N ha^{-1}, respectively. Plotted data from all seed yield and CI data obtained from this study highlighted the immense impact that seed yield has on CI. The regression model indicated the minimum CI (22.1 g CO_{2e} MJ^{-1}) was obtained with a seed yield of 1561 kg ha^{-1}. In the rainfed areas in the northern Great Plains, camelina can easily produce seed yields of 1100 kg ha^{-1}, which would have a CI of 30.1 g CO_{2e} MJ^{-1}. Overall, this study suggest that various nitrogen rates can increase camelina seed yield, which can offset the resulting increase in CI due to N fertilizer and N_2O emissions. Based on this study, N application rates should be less than 40 kg N ha^{-1} to minimize CI. These results confirm that camelina is not always a low CI feedstock. One single, default CI value for camelina oil-based jet fuel should not be used for estimations of greenhouse gases emissions reduction. The final CI of camelina-based jet fuel depends largely on seed yield and N_2O field emissions.

4. Impact Statement

The forage program at NDSU is the only program that provides non-biased information to farmers on the performance of forages and the environmental impact of them in North Dakota.

1. Forages production impact: Forages acreage, without including CRP or native rangeland was 3,076,081 acres in 2023. Forages are the fourth most important crop in acreage in North Dakota after soybean, wheat, and corn. Diverse studies in alfalfa management conducted by this project have demonstrated that forage yield can easily be increased on average at least by 0.3 ton/acre/yr. Alfalfa and alfalfa grass mixtures acreage in ND in 2023 was 1.53 million acres. An increase in forage yield of 0.3 tons/acre/year x 1,530,000 acres (alfalfa & alfalfa-grass) at $120/ton of hay equals an economic impact of **$55,080,000/yr** in economic revenue to North Dakota farmers.

2. Forage sorghum impact: Forage sorghum is drought tolerant and its feed quality is similar to silage corn. It can easily yield up to 10 tons of dry matter/acre in ND representing a gross income from $300 to $500 per acre considering at $30-50/ton for a biomass feedstock. In 2023, forage sorghum acres and sudangrass were 52,265 and 10,924 acres, respectively. At a $50/ton value by 10 tons/acre (2 cuts) as feed, the economic impact equals **$31,594,500/yr**.

3. Alfalfa-corn or sunflower intercropping at establishment impact: One of the goals of the forage project is to increase the acres of alfalfa in rotation with corn in the state. To do this profitably our research has shown alfalfa can be established while growing corn or sunflower. This system increases alfalfa yield in Year 2 by 2.5 tons/acre compared with a spring-seeded alfalfa. The net return of the 2-year system with alfalfa established in intercropping with the

cash crop in Year 1 can increase net returns by 60% in corn ($267/acre) and by ($452/acre) in sunflower compared with the business as usual of planting the cash crop in Year 1 and alfalfa in the spring of Year 2. The acres of corn silage-alfalfa rotation in ND are 200,000 acres x $267/ 2 = **$26,700,000/yr** in monetary impact. Acres of sunflower in rotation with alfalfa are only about 20%, 555,143 acres x 20%= 111,028 acres x $452/2= **$25,092,464/yr** in monetary impact.

4. Alfalfa nitrogen credits to corn impact: Including alfalfa in rotation with corn might become part of the solution to current high N fertilizer prices. Nitrogen credits of alfalfa to corn can be up to 150 lbs/acre. With a N fertilizer value of $0.8/lb and raising, this would be a potential saving of $120/acre. If we consider a saving of only $60/acre and 10% of the corn acreage in ND is planted after alfalfa in the rotation, the reduction in the cost of fertilizer would be 3,965,380 acres x 10% x $60/acre= **$23,792,280/ yr.**

5. Bioenergy crops-impact: This project also conducts research in winter oilseeds for biofuels, such as winter camelina which is highly winter hardy and serves as both a cover crop and cash grain crop and feedstock for sustainable aviation fuel (SAF). Commercial oil companies are projecting to have 1 to 2 million acres of winter camelina in ND the next 5 years for SAF production. Growing camelina in a wheat-soybean rotation can increase net revenue in ~ $100/acre, which would be **$100 to $200 million** in annual revenue.

Yearly, the impact of my project is modified with the current reports of acreages and prices of fertilizers or commodities.

5. Published written work

Peer-reviewed publications

Berti, M.T.*, Morocho-Lema, M., and Anderson, J.V., 2025. Sensitivity of winter and spring camelina to salinity during germination. Ind. Crops Prod. 232: 121293 https://doi.org/10.1016/j.indcrop.2025.121293

Ashworth, A.J., A. Tyson, T. Prospt, L. Marshall, J.J. Volenec, M.D. Casler, M.T. Berti, E. van Santen, V. Picasso, J.L. Foster, and J. Su. 2025. Knowledge graph applications for identifying resilient forage systems. Agricultural & Environmental Letters. DOI: 10.1002/ael2.70021

McGranahan, D.A., M.R. Wanchuck, K. Sedivec, M.T. Berti, K.C. Swanson, and T.J Hovick. 2025. Variability in weight gains of cows and their calves across grazing management and mother age class: Implications for maternal productivity. Rangeland Ecology & Management 100:121-125. https://doi.org/10.1016/j.rama.2025.03.001

Gesch, R.W., Eberle, C.A., Berti, M.T**.,** Ott, M., and Anderson J.V. 2025. Productivity and seasonal water use of double cropped dry bean, proso millet, and sunflower after early maturing winter camelina. Ind. Crop Prod.229 https://doi.org/10.1016/j.indcrop.2025.120953

Spiess, J., C. Gasch, D. McGranahan, T. Hovick, M.T. Berti, and B. Geaumont, B. 2025. Patch-burn grazing increased structural heterogeneity in southwestern North Dakota rangelands. Applied Vegetation Science DOI: 10.1111/avsc.70016

Igboke, O., Bortolon, E.S.O., Asworth, A. J., Tallaksen, J., Picasso, V.D., and Berti, M.T., 2024. Perennial forage systems enhance ecosystem quality variables compared with annual forage systems, Sustainability 16, 10160 https://doi.org/10.3390/su162310160

Scientific and Outreach Presentations

Berti. M.T. North Dakota forages report. Annual meeting NCCC31 Forage committee, Spring Hill, Tennessee 28-30 April 2025.

Berti, M.T., 2025. Cover crops research in North Dakota. Midwest Cover Crops Council, Mankato, MN, 27-29 January 2025.

Igboke, O. A. Kurth, H. Mosqueda, H. Lindell, Md. S. Islam, M. Morocho-Lema, F. Omeye, and M.T .Berti. Environmental Impact of Alfalfa and Winter Camelina Integrated into Wheat-Sunflower-Soybean Rotations. American Forage Grassland Conference Kissime, FL, 13-15 January 2025.

Islam, Md S., M.T. Berti, F. Omeye, H. Lindell, H. Mosqueda, A. Kurth, O. Igboke, M. Morocho, and M. Grijalba. 2024. Intercropping alfalfa and sainfoin with sunflower: Boosts forage production, soil health, and biodiversity {Abstract] ASA-CSSA-SSSA International Annual Meeting, San Antonio, TX, November 10-13, 2024.

Omeye, F., M.T. Berti, H. Mosqueda, H. Lindell, Md S. Islam, M. Morocho-Lema, and O. Igboke 2024. Intercropping perennial legumes with a warm-season grass to improve forage sustainability. [Abstract] ASA-CSSA-SSSA International Annual Meeting, San Antonio, TX, November 10-13, 2024.

Lindell, H., M.T. Berti, M.S. Islam, H. Mosqueda, M. Morocho, O. Igboke, and F. Omeye, 2024. Productivity in a spring wheat-winter camelina-sunflower sequence [Abstract] ASA-CSSA-SSSA International Annual Meeting, San Antonio, TX, November 10-13, 2024.

Igboke, O., Berti, M.T., and E. Bortolon, 2024. Sustainable cropping system diversification with improved ecosystem quality variables [Abstract] ASA-CSSA-SSSA International Annual Meeting, San Antonio, TX, November 10-13, 2024.

7. Collaborative grants (new)

1. Bayer Crop Science, 3/2025-3/2026Advanced Yield Trial Winter and Spring Camelina Lines 2025 $10,085 . PI
2. DOE- 1/2025-12/3031. OILSEED: OILseed Crops to Sustain the Environment and Meet Energy Demand $9,999,893. Co-Pi
3. USDA-NIFA 5/2024-4/2027. Plant Breeding CIN: Advancing Intercrop Breeding with Genomic and Phenomic Selection. $163,250. Co-PI Award #

8. Graduate students

Privillege Muleya, MS, Plant Sciences. Establishment methods of perennial pollinator mixes. Expected Graduation date May 2027, Advisor: Berti

Miguel Grijalba, MS, Plant Sciences, Root morphology in alfalfa. Expected Graduation date May 2027. Advisor: Berti.

Micah Gartenberg, PhD, Plant Sciences. Optimizing carbon intensity in cropping systems integrating *Camelina sativa* and alfalfa. Expected graduation date May 2028. Advisor: Berti. (Resilience-CAP)

Ogechukwu Igboke, PhD, Environmental and Conservation Sciences. Life cycle assessment of cropping systems. Expected graduation date, May 2027. Advisor: Berti (Resilience -CAP)

Maria Mazala, PhD, Plant Sciences. Transcriptomic analysis of sunflower-alfalfa intercropping. Expected graduation date, December 2026. Advisor: Berti
Shazzadul Islam, MS, Plant Sciences**.** Sunflower-alfalfa and sainfoin intercropping. Graduated: May 2025. Advisor: Berti
Franklin Omeye, MS, Plant Sciences. Forage-sorghum alfalfa and sainfoin intercropping. Expected graduation date: December 2025. Advisor: Berti
Haley Mosqueda, PhD, Environmental Conservation Sciences**.** Establishing alfalfa with corn and sorghum. Expected graduation date December 2025. Advisor: Berti (Resilience-CAP)
Nabi, Mohammad Al Mahmud, PhD, Microbiology**.** Changes in the soil microbiome in cropping systems Expected graduation date: May 2026. Advisor: Geddes
Garret Levin, PhD, Microbiology. *Sinorhizobium* in alfalfa. Expected graduation date: Expected graduation date: May 2026. Advisor: Geddes
Taonga Msimuko, MS, Plant Sciences. Companion crops for establishing Kernza. Expected graduation date Dec. 2026. Advisor: Keene
Maria Batool, PhD, School of Natural Resources, Carbon pools from grasslands and cropland in North Dakota, Expected graduation date. December, 2026. Advisor: Cihacek

Ohio
The Ohio State University (Chiavegato)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The forage group at The Ohio State University is conducting research on 1) agroecosystems resilience to recurring short-term flooding, 2) crop-livestock diversification, and 3) carbon footprint and sequestration potential of crop-livestock agroecosystems.

2. New Facilities and Equipment

- Wiley Mill

3. Unique Project Related Findings

We observed a consistent correlation between forage height and 95% light interception across both cool- and warm-season grass species. Each species reached 95% light interception, maximizing leaf production, at specific heights: 20 inches for native warm-season grasses such as Indiangrass and Big Bluestem, 13 inches for tall fescue and orchardgrass, 12 inches for Kentucky bluegrass, and 8 inches for white clover. The nutritive value of the warm-season grasses was comparable to that of cool-season grasses and met USDA premium grass hay quality guidelines.

4. Accomplishment Summaries

Establishment protocol for different warm-season grasses species

Native warm-season grasses (NWSG) adoption is limited, partly, due to establishment challenges, especially weed competition. The objective was to develop establishment protocols for switchgrass (SG) and eastern gamagrass (EG) and a mix of indiangrass and big bluestem (IG/BG) under organic and conventional herbicide management across three sites in Ohio from 2021-2024. Three strategies were evaluated:1) Conventional, no-till with herbicide, 2) Conventional + cereal rye cover crop (CC), 3) Organic, with tillage and summer (sorghum-sudangrass + cowpea) and fall (oats) cover crops. Organic treatments used no herbicide and Conventional treatments used glyphosate (SG, EG) or imazapic (IG/BG), with some sites receiving 2,4-D. Results demonstrate that in Conventional treatments, with and without cover crops, NWSG growth suppressed weeds and stabilized by year 2 and 3. The Organic system, consistently, had the lowest forage and the greatest weed mass. For most locations/years, the greater NWSG mass and cover and lowest weed mass and cover occurred in the IG/BG mix compared to SG and EG, probably due to the selective herbicide use reducing weed pressure and promoting faster forage growth. Forage nutritive value was greater in the IG/BG mix, but all NWSG species had moderate to good nutritive value, according to USDA hay standards, which does not specify animal category. In conclusion, the successful NWSG establishment required chemical weed control, while adding cover crops with herbicide was less effective than herbicide alone.

Comparing the environmental tradeoffs and synergies of alternative modes of integrating livestock into cash grain cropping systems

The project aims to identify strategies to improve the performance of integrated crop-livestock systems, document both opportunities and barriers to expanding the most promising approaches and develop recommendations for public and private interventions to accelerate their adoption. To achieve these goals, we are pursuing five interrelated objectives:

1. Quantify the diverse environmental outcomes associated with various livestock-crop integration methods under working farm conditions.
2. Assess the animal welfare and human health risks and benefits of increased manure use and greater livestock integration in cash grain cropping systems.
3. Develop whole-farm models to evaluate the socioeconomic, health/welfare, and environmental tradeoffs and synergies associated with each approach to livestock-crop integration.
4. Identify the social, technical, economic, and institutional constraints limiting the adoption of these methods on regional livestock and cash grain farms.
5. Use a participatory, on-farm approach to better integrate research and extension/outreach activities.

Field sample collection and analyses were completed in 2023, and data is currently being analyzed for publication.

Enhanced soil carbon farming as a climate solution – Grazing and Hay Systems

The adoption of soil-carbon-enhancing practices by farmers and ranchers requires a solid understanding of soil carbon sequestration practices and their agronomic and environmental benefits. To effectively translate these findings into soil management and conservation practices that enhance soil organic carbon sequestration across diverse agroecosystems, large-scale, on-farm data from croplands, grasslands, and rangelands are essential. Preliminary results indicate that higher carbon (C) levels are linked to greater soil fertility and improved physical conditions. Studies show that improved pasture management can increase C stocks by 10-50% compared to conventional practices. Perennial pastures, depending on tillage frequency, can boost C stocks by 50-200% compared to annual crops. However, long-term conventional grass hay management tends to have C stocks comparable to long-term conventional tillage cropping systems. Alfalfa, particularly when established over several years, has the potential to store significantly higher amounts of C.

Fostering Resilience: Integrating Planned Plant Diversity and Grazing Management for a Sustainable Strategy to Environmental Disturbances

In forage-based animal research, responses are often evaluated under grazing or fresh-cut conditions without detailed characterization of pasture structure. However, variation in canopy architecture, shaped by defoliation management, can influence both forage yield and composition. When defoliation strategy and the resulting pasture structure are not clearly defined or controlled, it may become difficult to interpret treatment effects associated with the forage diet. To investigate these dynamics, we established a greenhouse experiment that ran from August 2022 to August 2023. The study followed a completely randomized 2 × 5 factorial design

with three replicates, evaluating the effects of two defoliation targets based on canopy light interception (~95% and ~100%) applied to five functionally diverse forage grasses commonly grown in Ohio: tall fescue, orchardgrass, Kentucky bluegrass, big bluestem, and indiangrass. Light interception was measured regularly using a quantum sensor, and defoliation was applied when target thresholds were reached. Data from February to August 2023 were used in this analysis to ensure that plants had structurally adapted to the defoliation regimen. After each regrowth cycle, canopy height was recorded, forage was harvested, and tiller population density was assessed monthly. Tiller weight and green forage mass were determined at the final harvest. Agronomic traits included leaf, stem, and dead biomass yield. Despite differences in morphology and growth strategy, all species showed consistent structural adaptations. In general, the 95% light interception target generated shorter and denser canopies, with greater tiller population density (1813.8 vs. 1673.7 tillers m^{-2}; $P = 0.021$) and lower tiller weight (0.234 vs. 0.320 g DM; $P < 0.001$) compared to the ~100% target. Canopy height varied by species, with a significant interaction between species and defoliation target ($P = 0.009$). The 95% treatment also resulted in higher leaf yield (1,725.7 vs. 1,440.5 g DM m^{-2}; $P = 0.002$) and lower accumulation of stem (111.4 vs. 142.1 g DM m^{-2}; $P = 0.050$) and dead material (13.1 vs. 42.8 g DM m^{-2}; $P < 0.001$), likely due to reduced senescence. Conversely, green mass was higher under the ~100% light interception treatment (409.5 vs. 305.7 g DM m^{-2}; $P = 0.009$). These contrasting canopy structures led to distinct agronomic outcomes across species. The results show that defoliation frequency strongly influenced both pasture structure and forage yield, and that these effects were consistent regardless of species.

5. Impact Statements

   Soil Carbon Inputs and Storage in Flooded Pasture Fields of Southern Ohio

   Implementing improved management practices, such as rotational grazing, diverse species mixtures, and grazing cover crops, is crucial for further enhancing carbon (C) stocks in pastures prone to flooding. These practices contribute to better soil carbon inputs and storage, which are essential for building resilient agroecosystems in Southern Ohio.

   Fostering Resilience: Integrating Planned Plant Diversity and Grazing Management for a Sustainable Response to Environmental Disturbances

   This highlights the value of characterizing and managing pasture structure in forage-based animal studies. Without such control, pasture conditions may vary across defoliation cycles, creating confounding effects that limit the ability to explain animal responses. This experiment provides a conceptual basis for integrating structure-based management into animal science research.

6. Published Written Works

Barker, D.J, Sulc, R.M. Chiavegato, M.B. 2023. Chapter 9 – Pasture and Grazing Management. In Ohio Agronomy Guide. (16th Edition). *In press.*

Miquilini, M., Ribeiro, R.H., Bauman, S., Lyon, S.W., **Chiavegato, M.B.** 2024. Higher apical meristem in tall fescue as adaptation strategy to recurring short-term inundation in Ohio. *Agrosystems, Geosciences and Environment.* https://doi.org/10.1002/agg2.20486

Kannberg, S., Lindsey, A.J., **Chiavegato, M.B**., Lindsey, L.E. 2024. Effects of soybean planting date on soybeans grain yield within a rye cover crop system. *Agronomy Journal*. https://doi.org/10.1002/agj2.21550

Barker, D., **Chiavegato, M.B.**, Campbell, B., Verhoff, K. *In press*. Advances in sustainable sheep pasture and grazing management. In: Sheep Management. Burleigh Dodds Science Publishing.

Barker, D., **Chiavegato, M.B.**, Collins, M. *In press*. Forage Fertilization and Nutrient Management. In: Nelson, J., Collins, M., Moore, K. Forages, v. 1, 7 ed., Wiley Blackwell.

Barker, D.J, Sulc, R.M. **Chiavegato, M.B**. 2024. Chapter 9 – Pasture and Grazing Management. In Ohio Agronomy Guide. (16th Edition).

Chiavegato, M.B. 2024. Diversification and Integration: Lessons from Brazil in Carbon Loss Mitigation. Sustaining our Soils - An Animal Welfare Solution for the Environment and the Climate. Four Paws.

Chiavegato, M.B. 2025. A Deeper Look at Grazing Systems and Greenhouse Gases. The Journal of Nutrient Management.

7. Scientific and Outreach Presentations

Abstracts, symposium and conference presentations

1. Salsbury, L.F., **Chiavegato, M.B.** 2024.Grazing Management Practices on Productivity and Carbon Footprint of Grass-Fed Beef. [Abstract]. ASA, CSSA, SSSA International San Antonio, TX.
2. Borrenpohl, D., Ribeiro, R.H., **Chiavegato, M.B.** 2024. Co-Composted Biochar Impacts on Soil Health, Crop Yields, and Greenhouse Gas Emissions in an Integrated Crop-Livestock System. [Abstract]. ASA, CSSA, SSSA International San Antonio, TX.
3. Ribeiro, R.H., Salsbury, L.F., **Chiavegato, M.B.** 2024. Relationships between Management Choices and Soil Carbon Stocks in Ohio's Forage Production Systems: An on-Farm Approach. [Abstract]. ASA, CSSA, SSSA International San Antonio, TX.
4. Stachler, C., Mammana, A.F., Ribeiro, R.H., **Chiavegato, M.B**. 2024. Associated Effects of Grazing, Inundation, and Forage Mixtures on Soil Greenhouse Gas Emissions in Ohio. [Abstract]. ASA, CSSA, SSSA International San Antonio, TX.
5. Otaviano, E.K.S., Ribeiro, R.H., Lyon, S., Haden, V.R., Jackson-Smith, D., **Chiavegato, M.B.** 2024. Long-Term Impacts of Diverse Management on Forage Quality in Ohio's Working Farms. [Abstract]. ASA, CSSA, SSSA International San Antonio, TX.

6. Gelley, C., Rodriguez-Hernandéz, C.Y., **Chiavegato, M.B.** 2024. Expanding Options for Establishment Methods of Native Warm-season Grasses in Eastern Ohio. American Forage and Grasslands Council, AL.

8. Collaborative Grants

Chiavegato, M.B., Matcham, E.G., Essman A. Ribeiro, R.H., Otaviano, E.K.S., Sbrissia, A. 2025. Mimicking Nature: Establishment Protocols for Warm- and Cool-Season Grass Mixtures. The Greenacres Foundation, $280,320. 2025.

9. Graduate students

Indicate name, MS or PhD, graduation date or expected graduation date, thesis title

Mammana, Alexandre F. PhD. Expected graduation date: April 2025. Planned species diversification and strategic grazing management to increase system resilience and productivity.

Salsbury, Lydia. Graduate May 2025. Carbon inputs from manure, plants, and roots to Carbon soil stocks in grazed pastures and hayfields.

Borrenpohl, Daniel. Expected graduation date December 2028. Co-Composted Biochar Impacts on Soil Health, Crop Yields, and Greenhouse Gas Emissions in an Integrated Crop-Livestock System.

Oregon
Oregon State University (Hannaway)
NCCC-31 Ecophysiological Aspects of Forage Management

This work supported by USDA-AFRI AFRI COMPETITIVE GRANT AGREEMENT NO: 2021-68012-35917

1. Impact Nuggets

Development of new methodology or approaches:

- Using climatic and soil factors in spatial data layers to map forage species suitability zones. (David Hannaway)

Implementation of solutions or adoption of recommendations developed:

- Updating a Species Selection web segment for matching climate and soil conditions with quantitative forage species tolerances. (David Hannaway)

Cleaner environment and healthier communities:

- Increasing the use of forage species in grazing pastures to reduce methane emissions, urine leaching to the groundwater, and increasing atmospheric nitrogen fixation to lower nitrogen fertilizer demands. (Serkan Ates)

Developing the next generation of scientists:

• Serving as mentor for graduated MS student creating GIS-based species suitability maps. (David Hannaway)

- Utilizing College of Agricultural Sciences resources for Undergraduate Research Assistants. (David Hannaway and Linda Brewer)

2. New Facilities and Equipment: NA.

3. Unique Project Related Findings: NA.

4. Accomplishment Summaries

National Collaborative Efforts: Collaboration with PRISM Group scientists Chris Daly and Michael Halbleib, world climate center calculations for future species suitability, and numerous US Extension and research scientists for forage species knowledge. Collaboration with Jame Foster (Texas A&M University) for fact sheets on warm season forage species (David Hannaway)

Oregon Collaborative Efforts: Oregon State University Extension and Research faculty working together through a "Forage and Livestock Systems" Extension (and Research and Teaching) Working Group. This work group has increased collaboration on planning and execution of high priority projects in sustainable forage-livestock systems. Participants have upgraded the MatchClover into the MatchForage forage species information and selection tools. Linkage also includes collaboration with the Oregon Forage & Grasslands Council including farmers and ranchers. [David Hannaway, Mylen Bohle, Serkan Ates, Gordon Jones, and Shelby Filley and Seed Company forage scientists (DLF and Barenbrug)].

- A MatchForage website (https://forages.oregonstate.edu/matchforage) has been created to present comprehensive content of forage species to support sustainable agricultural systems. This site simplifies the search for information by county agents and specialists, farmers and ranchers, and agricultural agency personnel and builds stronger linkages among research, outreach, and classroom and eCampus teaching efforts (Working Group participants).
  - Progress to date includes developing the organizational outline of dozens of species fact sheets, numerous sub-topics, and content authors. Initial drafts have been completed for many of the sections and a review process has been developed that is consistent with University Extension Service catalog. This review process is necessary for ensuring "scholarly accomplishments" credit for authors.
  - A uniform template includes: Description and Uses, Identification, Cultivar Types, Suitability Zones, Suitability Maps (based on quantitative tolerances and GIS gridded data), Seasonal Production Profiles, Phenological Development (Bloom time for legumes), Establishment and Management, Quality and Antiquality, Image Gallery, Resources, Authors, Reviewers, and Funding Support.
  - The primary challenges remaining for completion of these fact sheets include developing USA maps for suitability (based on minimum and maximum temperature, annual precipitation, pH, soil drainage, and salinity), and Seasonal Production Profiles and Phenological Development graphics based on photo-thermal time. University scientists and seed industry personnel have developed a maturity index for cool-season grasses with several national field sites.

Research: PI and Project Descriptions

Serkan Ates: Evaluation of novel forage species, especially legumes and other forbs, to diversify forage production and extend the grazing season for dairy and sheep grazing systems.

David Hannaway: Modeling and mapping of forage species suitability leading to improved species and cultivar selection.

1. ***Modeling Potential Seasonal and Annual Yield***

   This project is using crop simulation modeling to estimate forage production potential across the landscape. Work is a collaborative effort involving faculty and students from Lincoln University (NZ), China Agricultural University (PRC), Jiangsu Academy of Agricultural Sciences (PRC), and Oregon State University (OSU).

   The NZ focus is alfalfa within grazing systems. US focus and Oregon scope is alfalfa and grass hay production and mixed clover-grass pastures. Seasonal and total annual yield will be predicted using crop simulation models, with assistance from AgMIP program organizers from the University of Florida.

   New Zealand work is compiling previous modeling experiments into a new modeling platform called APSIMX-Lucerne.

   Chinese work is developing a web-based modeling platform called AgroStudio using Python modeling language. Currently in Chinese language but anticipate adding English.

   Collaborators include: Derrick Moot and Xiumei Yang (Lincoln University), FENG Liping (China Agricultural University), CAO Hongxin (Jiangsu Academy of

Agricultural Sciences), and OSU faculty: Chris Daly, Mike Halbleib, Len Coop, and Serkan Ates and Guojie Wang (PSU).

2. **Developing a Maturity Index for Cool-season Grass Species and Cultivars**

   Phenological development is an important management indicator for forage species since quality and quantity are closely related to plant maturity at harvest. Climate-based maturity stage timing estimates are needed for all species and cultivars in all global locations for selecting planting mixtures and formulating recommendations for cutting management, forecasting forage quality, and estimating forage production potential.

   This project is developing a universal maturity index for cool-season forages grasses by creating a function that includes photoperiod and temperature-mediated development parameterized for each species, ecotype, and cultivar of key cool-season forage grasses.

   Collaborators include: Roeland Kapsenberg, Steve Reid, and Jerome Magnuson (DLF); Serkan Ates, Len Coop, Mylen Bohle, and Shelby Filley (OSU); Guojie Wang (PSU), Liping Feng (China Agricultural University); Feng He and Xianglin Li (Chinese Academy of Agricultural Sciences); Derrick Moot (Lincoln University, NZ); Peter Ballerstedt (Barenbrug USA); Jerry Hall (Grassland Oregon).

3. **Modeling and Mapping Suitability Zones for Alfalfa Cultivar Types**

   This project is modeling and mapping the 11 fall dormancy (FD) and 6 winter survival index (WSI) types of alfalfa by defining their quantitative tolerances. Logistic and Gaussian functional relationships are being parameterized for covering the entire range of values for climate and soil conditions. Each FD and WSI value will be characterized and mapped to display the areas best suited for cultivar classification. Validation work with crop simulation models will utilize existing field trial information from all alfalfa-growing regions in the US and China.

   Collaborators include: Feng He and Xianglin Li (Chinese Academy of Agricultural Sciences); Liping Feng (China Agricultural University); Derrick Moot (Lincoln University, NZ); Len Coop, and Mylen Bohle (OSU), and Guojie Wang (PSU).

4. **Evaluation of Warm-season Grasses for Use in Oregon**

   Seasonal distribution of forage growth of cool-season species leaves a summer production gap that could be filled by warm season annuals and perhaps some cold-tolerant perennials. Project is consistent with AES Hatch funds collaborative project proposal and Guojie Wang's initial research plan as a Forage Extension Agronomist at Penn State University.

   Collaborators include: Guojie Wang (PSU), and Serkan Ates and Mylen Bohle (currently retired) (OSU).

5. Published Written Works

Recent Refereed Publications

In Progress

Krecklow, Emilie; Michael Halbleib; Chris Ringo; Chelsea Clark; David B. Hannaway, and Linda Brewer. 202X. Developing climatic and edaphic response functions for forage species relative yield estimates for conterminous USA-wide GIS maps.

2024

Meador, M.A., Ates, S., & Kutzler, M.A 2024. Feeding spent hemp biomass does not adversely affect fertility in rams. American Journal of Veterinary Medical Research, 1(aop), 1-8. https://doi.org/10.2460/ajvr.24.05.0134

Irawan, A., Muchiri, R. N., Parker, N. B., van Breemen, R. B., Ates, S., & Bionaz, M. 2024. Cannabinoid residuals in tissues of lambs fed spent hemp biomass and consumer's exposure assessment. Food and Chemical Toxicology, 114848. https://doi.org/10.1016/j.fct.2024.114848

Andrew, A. C., Higgins, C. W., Smallman, M. A., Prado-Tarango, D. E., Rosati, A., Ghajar, S., Graham, M., & Ates, S. 2024. Herbage and sheep production from simple, diverse, and legume pastures established in an agrivoltaic production system. Grass and Forage Science, 1–14. https://doi.org/10.1111/gfs.12653

Irawan, A., Puerto-Hernandez, G. M., Ford, H. R., Busato, S., Ates, S., Cruickshank, J., ... & Bionaz, M. 2024. Feeding spent hemp biomass to lactating dairy cows: effects on performance, milk components and quality, blood parameters, and nitrogen metabolism. Journal of Dairy Science. https://doi.org/10.3168/jds.2023-23829

2023

David B. Hannaway, Linda Brewer, and Kayleen Schreiber. 2023. Fostering Resilience in Landscapes: Integrating Diverse Perennial Circular Systems; Objective 1.1: Identifying Appropriate Forage Species. XXV International Grassland Congress, Kentucky.

Peter J. Ballerstedt, David B. Hannaway, T.D. Noakes. 2023. Why We Need a Ruminant Revolution: Combating Malnutrition and Metabolic Illnesses to Enable Sustainable Development. International Grassland Congress. Theme 3-1, 19. Univ. Kentucky: UKnowledge. https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=4265&context=igc

Teixeira, Edmar,Jing Guo, Jian Liu, Rogerio Cichota, Hamish Brown, Abha Sood, Xiumei Ya ng, David Hannaway, Derrick Moot. 2023. Assessing land suitability and spatial variability in lucerne yields across New Zealand. European J. Agron. Vol. 148. Vol. 148, August, 126853. https://doi.org/10.1015/j.ega.2023.126853

Caudillo, M., Melathopoulos, A., Prado-Tarango, D. E., Smallman, M., Taylor, S. A., & Ates, S. 2023. Designing Management Strategies for Sheep Production and Bees in Dryland Pastures. Agronomy, 14(1), 24. https://doi.org/10.3390/agronomy14010024

Seeno, E., MacAdam, J.W. Melathopoulos, A., Filley, S.J. and Ates, S. 2023. Management of perennial forbs sown with or without self-regenerating annual clovers for forage and nectar sources in a low-input dryland production system. Grass and Forage Science https://doi.org/10.1111/gfs.12640

Rosati A., Procter, K., Dazae, A., Graham, M., Ates, S., Kirschten, H., & Higgins, C. 2023. Agroforestry vs. Agrivoltaic: spectral composition of transmitted radiation and implications for understory crops. Agroforest Syst. https://doi.org/10.1007/s10457-023-00914-3.

2022

Mai, Kai,l Zhu Yu, Shuai Huang, Musen Wang, David B. Hannaway. 2022. Effect of Storage Period on the Fermentation Profile and Bacterial Community of Silage Prepared with Alfalfa,

Whole-Plant Corn and Their Mixture. Fermentation 2022, 8(10), 486; https://doi.org/10.3390/fermentation8100486

Li, Z., F. He, Z. Tong, X. Li, Q. Yang, D.B. Hannaway. Metabolomic changes in crown of alfalfa (*Medicago sativa* L.) during de-acclimation. Sci Rep 12, 14977 (2022). https://doi.org/10.1038/s41598-022-19388-x

Valentin D. Picasso, Marisol Berti, Kim Cassida, Sarah Collier, Di Fang, Ann Finan, Margaret Krome, David Hannaway, William Lamp, Andrew W. Stevens, Carol Williams. Diverse perennial circular forage systems are needed to foster resilience, ecosystem services, and socioeconomic benefits in agricultural landscapes. 2022. Grassland Research Vol. 1, Issue 2, p. 123-130. https://doi.org/10.1002/glr2.12020

Parker, N. B., Bionaz, M., Ford, H. R., Irawan, A., Trevisi, E., & Ates, S. 2022. Assessment of spent hemp biomass as a potential ingredient in ruminant diet: Nutritional quality and effect on performance, meat and carcass quality, and hematological parameters in finishing lambs. Journal of Animal Science. skac263, https://doi.org/10.1093/jas/skac263

Anderson, J.D., Ochoa, C.G., Sahin M. and Ates, S. 2022. The effects of self-regenerating annual clovers on plant species composition and heifer performance in an irrigated pasture in western Oregon, USA. Grassland Science doi: https://doi.org/10.1111/grs.12378

Seeno, E., Naumann, H., and Ates, S. 2022. Production and chemical composition of pasture forbs with high bioactive compounds in a low input production system in the Pacific Northwest. Animal Feed Science and Technology, 289, 115324. https://doi.org/10.1016/j.anifeedsci.2022.115324

Louhaichi, M., Hassan, S., Gamoun, M., Safi, N., Abdallah, M. A., & Ates, S. 2022. Evaluation of rainwater harvesting and shrub establishment methods for sustainable watershed management in northern Afghanistan. Journal of Mountain Science, 1-14. https://doi.org/10.1007/s11629-021-7172-x

E*xtension Publications*

Under Development

A MatchForage website (https://forages.oregonstate.edu/matchforage) has been created to present comprehensive content of forage species to support sustainable agricultural systems. Sixty species have been identified and are being developed as part of the USDA Sustainable Agricultural Systems grant project.

i.e. Hannaway, David B., Mylen Bohle, Gordon Jones, and Linda Brewer. Growing Cereal Grains for Forage.

[Individual species fact sheets also drafted for Barley, Oat, Rye, Triticale, and Wheat]

6. Scientific and Outreach Presentations:

2023 International Grasslands Congress

David B. Hannaway, Linda Brewer, and Kayleen Schreiber. 2023. Fostering Resilience in Landscapes: Integrating Diverse Perennial Systems. Objective 1.1: Identifying

Appropriate Forage Species. XXV International Grasslands Congress. Covington, KY, USA.

Ates, S. and Bionaz M. Feeding spent hemp biomass and its evaluation. Cutting-Edge Science Symposium on "Efficient use of plant biomass for different feedstocks: Challenges and opportunities", Canberra, Australia. 7-9 March 2023 (key-note)

2022

David B. Hannaway. 2022. Oregon Forage Projects. NCCC-31 Annual Meeting. June 15-17, Laramie, WY.

Mylen Bohle, Serkan Ates, and David B. Hannaway. 2022. Oregon Forage Projects. WERA-1014 Annual Meeting. Corvallis OR August 31-September 1 2022.

Ates, S. Effect of pasture species with high bioactive compounds on milk yield, animal health and environment. 2022 ACS Annual Conference, Blazing the Trail for Cheese Portland, Oregon July 20-23, 2022 (Invited talk)

Ates, S. Sustainability in Pasture-based Livestock Production 9th International Conference on Sustainable Agriculture and Environment (ICSAE-IX) Online Conference, 24-25 August 2022, Surakarta, Indonesia (Invited talk)

Ates, S. Sustainable livestock production from phytochemically diversified pastures (2022) ASAS-CSAS Annual Meeting, June 26-30, 2022, Oklahoma City, Oklahoma (Invited talk)

Ates, S. Assessment of Spent Hemp Biomass as a Potential Feedstuff in Lamb Production. The Third Biennial Australian Industrial Hemp Conference Launceston, Tasmania 22nd - 25th March 2022 (Invited talk)

7. Collaborative Grants

Valentin Daniel Picasso Risso, Andrew W. Stevens, Ann Finan, Marisol Berti, Kim Cassida, David Hannaway, and Carol Williams. 2021. Fostering Resilience and Ecosystem Services in Landscapes by Integrating Diverse Perennial Circular Systems (Resilience CAP). NIFA-SAS-CAP Project September 1, 2021– August 31, 2026. $ 10,000,000. Oregon collaborators also include Linda Brewer, Serkan Ates, and Gordon Jones.

Ates, S. et al. 2020-2021. Methane emissions from grazing and confined dairy cows in the PNW. Oregon Dairy Farmers' Association.

Ates, S. et al. 2020. Feeding spent hemp biomass to lambs as a model for cattle: cannabinoid residuals, animal health, and product quality. Oregon Beef Council.

Ates, S. et al. 2020. Lamb growth, grazing behavior and welfare in agrivoltaic systems. Oregon State University Agricultural Research Foundation Grant.

Ates, S. 2020. Improving Soil Biodiversity and Grazing Days with Cover Crops on Irrigated Pasture in Oregon's High Desert. USDA Western Sustainable Agriculture Research and Extension (SARE) Farmer Rancher Researcher Grant.

Bionaz Massimo, S. Ates, and M. Smallman. 2020-2021. Legume hay with high bioactive compounds and organic selenium to improve the transition from pregnancy to lactation using sheep as animal model. Oregon State University Agricultural Research

Foundation Grant.

Bionaz Massimo, S. Ates, J. Duringer, and J. Cruickshank. 2020-2021- Feeding dairy cows spent hemp biomass instead of alfalfa: effect on health and performance of cows and cannabinoids residuals in milk (Oregon Dairy farmers Association).

Duringer Jennifer, Serkan Ates, Bionaz Massimo. 2020. Nutritional and potency characterization of hemp as a possible feed source for livestock. Oregon State University Agricultural Research Foundation Grant.

Melathopoulos, A., M. Moretti, and S. Ates. 2020-2022. New opportunities for establishing NRCS pollinator habitat in the Pacific Northwest. Natural Resources Conservation Service, USDA.

Melathopoulos, Andony and S. Ates. 2019-2020. Evaluating the nectar and pollen resources of alternative livestock forages to alfalfa. National Honey Board.

8. Graduate Students:

Clark, Chelsea. 2023. Application of Arc GIS Suitability Mapping Methodology to Develop an Ecological Restoring Monitoring Framework for the Crooked River, Oregon. Master of Science Thesis. Oregon State University. (David Hannaway)

Parker, Nathan. 2024. Spent Hemp Biomass in Livestock Diets: Effects on Animal Health, Performance and Meat Quality Attributes. PhD Thesis. Oregon State University (Serkan Ates).

Irawan, Agung. 2024. A Study of Suitability and Safety of Spent Hemp Biomass as a Feed Ingredient for Ruminants. PhD Thesis. Oregon State University (Serkan Ates and Massimo Bionaz).

Valliere, Sam. 2024. Soil Carbon, Conservation Practices, and Modeled Greenhouse Gas Emissions on an Oregon Sheep and Beef Ranch. Master of Science Thesis. Oregon State University. (Serkan Ates and Ricardo Mata Gonzalez).

Seeno, Elizabeth, Annie. 2023. Development and evaluation of chicory varieties containing high bioactive compounds. PhD Thesis. Oregon State University (Serkan Ates).

Caudillo, Mia. 2023. Development of dual-use pasture systems for livestock and pollinators. Master of Science Thesis. Oregon State University. (Serkan Ates)

Kirschten, Haley. 2023. The effect of supplementing dried chicory roots rich in sesquiterpene lactones and condensed tannins on parasite loads and immune system of lambs. Master of Science Thesis. Oregon State University. (Serkan Ates)

Ford, Hunter, Robert. 2023. Understanding the role and functions of plant secondary compounds on animal production and health. PhD Thesis. Oregon State University (Serkan Ates and Massimo Bionaz).

Andrew, Alyssa, Christine. 2022. Development of pasture systems for agrivoltaics Master of Science Thesis. Oregon State University. (Chad Higgins and Serkan Ates)

Anderson, Jordan. 2022. Livestock grazing in riparian areas: A comparison of land management practices in lowland dairy pastures and upland sheep pasture systems of Western Oregon. Master of Science Thesis. Oregon State University. (Carlos Ochoa and Serkan Ates).

Pennsylvania
Pennsylvania State University (Wang)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The forage team at Penn State conducted multiple research projects on 1) diversifying corn silage production systems, 2) renovating alfalfa agronomic management practices, and 3) soil health under short-term perennial forage rotation in the organic grain farming systems. We carried out the Hay Production Workshops (3), Pasture Production Workshops (3), Baleage Production Workshops (3), and Forage Webinar (1) with a high number of registrations and attendance.

2. New Facilities and Equipment

Forage harvester RCI 36A, silage harvester 130S

3. Unique Project-Related Findings

Young seedlings in the early crop development stages significantly impact silage crop performance and resource allocation through root exudates in the corn, sorghum, and soybean intercropping system.

4. Accomplishment Summaries

The forage team at Penn State continued an ongoing perennial forage grasses harvest stubble height project that initiated in 2020 and ends in 2025. An M.S. graduated from this project in 2024, and the final findings will be published in 2025 after the last harvest in September. We studied white clover living mulch under the corn silage production system, intercropping of sorghum or soybean in the corn silage production system, and searched for alternatives to replace rye in the corn silage + ryelage double cropping systems. Two M.S. graduate students will graduate in December 2025. Collaborating with Virginia Tech, an alfalfa project was initiated in spring 2025 to renovate alfalfa agronomic management practices, including variety selection, harvest interval and timing, and harvest stubble height. A Ph.D. student was recruited for this project. A two-year forage rotation in organic farming is out of the traditional forage research considerations. We studied six forage species with three functional groups in monocultures and polycultures to elucidate soil health under the short-term forage rotation. A Ph.D. student was recruited for this project starting in August 2025. The forage team at Penn State also performed multiple extension programs, produced a set of articles and factsheets, and diversified our delivery methods to focus on podcasts and YouTube channels. An undergraduate senior-level forage production course was taught successfully with high enrollment and student evaluations.

5. Impact Statement

All the research projects at Penn State are applied and field-based, focusing on forage producers' needs and answering their questions. We educated producers and industry personnel about the benefits forage has to our agricultural landscape and agroecosystems for short-term impact. We also expect forage producers to adopt the best management practices on forage species selection, soil testing, and harvesting, to balance forage production and environmental quality, especially water quality in PA, to improve forage production profitability and sustainability for long-term impact.

6. Published Written Works

Peer-reviewed journal articles:

Zhu, Y., **Wang, G.**, Xin, Z., Wang, A., & Ma, Y. (2024). The Annual Dynamics of the Water Source of an Ammopiptanthus mongolicus Community in the Gobi Desert of the Mongolian Plateau. MDPI-Forests 15(12), 12. DOI: 10.3390/f15122117

Zhao, B., Ata-Ul-Karim, S. T., Gao, Y., Feng, W., **Wang, G.**, Qin, A., & Liu, Z. (2024). Exploring the Impacts of Pre-Stem Elongation Nitrogen Status on Winter Wheat's Subsequent Growth and Nitrogen Status Using Nitrogen Nutrition Index. SSRN, 48. DOI: 10.2139/ssrn.4935006

Zhang, K., Cen, R., Moavia, H., Shen, Y., Ebihara, A., **Wang, G.**, Yang, T., Sakrabani, R., Singh, K., Feng, Y., Lian, F., Ma, C., & Xing, B. (2024). The Role of Biochar Nanomaterials in the Application of Environmental Remediation and Pollution Control. Chemical Engineering Journal, 19. DOI: 10.1016/j.cej.2024.152310

Zhang, Y., Chang, X., Zhang, Y., Wilkes, A., & **Wang, G.** (2024). Litter Accumulation Suppresses Grass Production but Facilitates Shrub Expansion in a Long-Term Fenced Grassland. Ecosphere 15(4), 12. DOI: 10.1002/ecs2.4844

Cao, W., Wu, X., Zhu, N., Meng, Z., Lv, C., Li, X., & **Wang, G.** (2024). Most Suitable Plant Communities for the Slope Reclamation of the Zhengzhou-Xinxiang Section of the Beijing-Hong Kong-Macao Expressway. Plos One 19(2), 15. DOI: 10.1371/journal.pone.0297004

Outreach publications:

Wang, G. & Carrijo, D. (2024). "Penn State Official Variety Trials Update." Field Crop News.

Carrijo, D., Murillo-Williams, A., Williams, C. J., van Saun, R. J., Esker, P. D., Thompson, N. S., & **Wang, G.** (2024). "Managing Crops Damaged by Mid-to-Late Season Flooding." Field Crop News.

Wang, G. (2024). "Seeding and Harvesting Perennial Forages on Time in the Fall." Field Crop News.

Wang, G. (2024). "Grazing Management of Endophyte-Infected Tall Fescue." Field Crop News.

Xue, W. & **Wang, G.** (2024). 2024 Forage Variety Trials Report.

7. Scientific and Outreach Presentations

Koirala, N., Contosta, A. R., Duque, L., Smith, R. G., **Wang, G.**, & Lowry, C. (November 9, 2024 - November 12, 2024). "Developing Climate Resilient Forage System for Future Warmer Conditions: An Experimental Approach," 2024 ASA-CSSA-SSSA International Annual Meeting, San Antonio, TX, USA, published in proceedings, Contributed. International.

Value of Perennial Forages in Annual Cropping Systems, Instructor, Lecture, External to Penn State, Keystone Crops and Soils Conference, Grantville, PA, 30 participants, Professional. Fall (October 31, 2024).

Grazing or Feeding Forages to Gain 2 Pounds Per Day: Myth or Reality?, Instructor, Lecture, External to Penn State, University Park, PA, 60 participants, Professional. Fall (October 8, 2024).

Corn Silage, Perennial Grasses, and Alfalfa Forage Utilization and Cash Crop-Forage Rotation, Instructor, Lecture, External to Penn State, Growmark FS, Hershey, PA, 150 participants, Professional. Fall (September 19, 2024).

Nitrogen Fertility and Molasses on Grass Hay, Co-Instructor, Extension Program, External to Penn State, Landisville, PA, 90 participants, Professional. Summer (August 1, 2024).

Forage Diversity and Phenology, Instructor, Extension Program, External to Penn State, 2024 Penn State Agronomic Field Diagnostic Clinic, Rock Springs, PA, USA, 65 participants, Professional. Summer (July 18, 2024).

Forage Quality, Testing, and Management, Instructor, Extension Program, External to Penn State, 2024 Lycoming Hay Workshop, Montoursvile, PA, USA, 11 participants, Professional. Spring (March 27, 2024).

Species Selection and Establishment, Instructor, Extension Program, External to Penn State, 2024 Lycoming Hay Workshop, Montoursville, PA, USA, 11 participants, Professional. Spring (March 27, 2024).

Forage Quality, Testing, and Management, Instructor, Extension Program, External to Penn State, 2024 Susquehanna Hay Workshop, Montrose, PA, USA, 22 participants, Professional. Spring (March 22, 2024).

Species Selection and Establishment, Instructor, Extension Program, External to Penn State, 2024 Susquehanna Hay Workshop, Montrose, PA, USA, 22 participants, Professional. Spring (March 22, 2024).

Grazing Season Extension and Soil Health Under Pasture, Instructor, Extension Program, External to Penn State, 2024 York County Winter Beef Meeting, York, PA, USA, 8 participants, Professional. Spring (March 20, 2024).

Silage Additives, Instructor, Extension Program, External to Penn State, 2024 SW Pennsylvania Regional Dairy Day, Scottdale, PA, USA, 118 participants, Professional. Spring (March 7, 2024).

Value of Perennial Forages in Annual Cropping Systems, Instructor, Extension Program, External to Penn State, 2024 Virtual Forage Webinar, On-line, 28 participants, Professional. Spring (March 6, 2024).

Matching Forage to Livestock Needs, Instructor, Extension Program, External to Penn State, 2024 Armstrong Pasture Workshop, Kittanning, PA, USA, 16 participants, Professional. Spring (March 5, 2024).

Hay Preservatives and Silage Additives, Instructor, Extension Program, External to Penn State, 2024 Tioga Crops Day, Wellsboro, PA, USA, 56 participants, Professional. Spring (March 1, 2024).

Corn Silage Traits - Are They Worth It?, Instructor, Extension Program, External to Penn State, 2024 Somerset Crops Day, Somerset, PA, USA, 23 participants, Professional. Spring (February 27, 2024).

Hay Preservatives and Silage Additives, Instructor, Extension Program, External to Penn State, 2024 Somerset Crops Day, Somerset, PA, USA, 23 participants, Professional. Spring (February 27, 2024).

Forage Pathogens & Growing Healthy Forages, Instructor, Extension Program, External to Penn State, 2024 Homestead Nutrition Agronomy Meeting, New Holland, PA, USA, 76 participants, Professional. Spring (February 21, 2024).

Grazing Season Extension and Soil Health Under Pasture, Instructor, Extension Program, External to Penn State, 2024 Western PA Winter Beef Meeting, Mercer, PA, USA, 24 participants, Professional. Spring (February 15, 2024).

Grazing Season Extension and Soil Health Under Pasture, Instructor, Extension Program, External to Penn State, 2024 Western PA Winter Beef Meeting, Greensburg, PA, USA, 13 participants, Professional. Spring (February 14, 2024).

BMPs for Small Grain Silage, Instructor, Extension Program, External to Penn State, 2024 Lebanon Crop Conference, Lebanon, PA, USA, 12 participants, Professional. Spring (February 6, 2024).

Sorghum, Sorghum-Sudan, and Sudangrass Silages, Instructor, Extension Program, External to Penn State, 2024 Lebanon Crop Conference, Lebanon, PA, USA, 15 participants, Professional. Spring (February 6, 2024).

Soil Health under Pastures, Instructor, Extension Program, External to Penn State, 2024 Southwest PA Soil Health Conference, Latrobe, PA, USA, 23 participants, Professional. Spring (January 31, 2024).

Hay Preservatives and Silage Additives, Instructor, Extension Program, External to Penn State, 2024 York County Crops Day, York, PA, USA, 84 participants, Professional. Spring (January 25, 2024).

Hay Stands Longevity under Drought and Low Fertility, Instructor, Extension Program, External to Penn State, 2024 York County Crops Day, York, PA, USA, 84 participants, Professional. Spring (January 25, 2024).

8. Collaborative Grants

The Rebellion of the Queen: Alfalfa as the Optimum Forage for Climate-Smart Dairy Systems. USDA-NIFA. 09/30/2024-09/29/2027. $299,946.

Comparing Soil Health and Weed Suppression within Organic Annual and Perennial Rotations. USDA-NIFA. 09/01/2023-08/31/2027. $999,994.

9. Graduate Students

Ream, A., M.S. (AEPS, Plant Science). Stage of Completion: In Process. (August 21, 2023 - Present).

Earnest, E., M.S. (AEPS, Plant Science). Stage of Completion: In Process. (August 21, 2023 - Present).

Rice, T. (Agronomy, Agronomy & Horticulture, University of Nebraska). Stage of Completion: Completed. (August 2022 - August 2024).

Tennessee
University of Tennessee (Renata Nave Oakes)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

ACCOMPLISHMENTS

Short-term Outcomes:
This year, we focused on the evaluation of plant growth-promoting bacteria (PGPB) in bermudagrass forage systems, under both greenhouse and field conditions. The research included testing *Azospirillum* Ab-V5 and Ab-V6, *Bacillus subtilis*, *Paenibacillus riograndensis*, and *Methylobacterium symbioticum*, with and without nitrogen fertilization at different rates. Early results indicate that PGPB can improve bermudagrass productivity, particularly under reduced nitrogen inputs, reinforcing their potential as sustainable tools in forage-based livestock systems.

Outputs:
Preliminary results were presented at regional scientific meetings and used to support a grant proposal submitted to a USDA-NIFA program focused on climate-smart agricultural practices. Data analysis is underway to prepare at least one peer-reviewed publication and additional extension materials for forage producers in the southeastern U.S.

Activities:
Field trials were conducted in Crossville, Tennessee, using randomized complete block designs. Treatments included bacterial inoculants with and without nitrogen, applied to 'Coastal' bermudagrass. Greenhouse trials were used to isolate effects under controlled conditions. Sampling included forage biomass, nitrogen uptake, chlorophyll index, and soil nutrient analysis.

Milestones:
– Established two successful field trials evaluating PGPB in bermudagrass systems.
– Completed greenhouse experiment under controlled conditions.
– Presented preliminary results at regional meetings.
– Submitted a new proposal for expanded work on biological inputs for forage systems.

IMPACTS

The integration of PGPB into forage systems such as bermudagrass may offer a promising alternative to synthetic nitrogen fertilization, potentially reducing input costs and environmental impacts. Early findings show that certain bacterial strains enhance bermudagrass growth even at reduced N rates, suggesting their role in improving nutrient efficiency. These biological tools align with climate-smart agriculture goals and could improve long-term sustainability and productivity of livestock-forage systems in the southeastern U.S. Adoption of PGPB-based management strategies has the potential to reduce nitrate leaching and greenhouse gas emissions, while maintaining or improving forage yield and quality.

PUBLICATIONS

Nave, R.L.G., O.G. Almeida *, J.J. Tucker, and Xiong, Y.V*. 2024. Restoring ecosystems in the Southeastern U.S. by interseeding alfalfa in existing cool-season grass pastures. Grassland Science. doi.org/10.1111/grs.12434.

Corbin, M.D.*, R.L.G. Nave, H. Naumann, G. E. Bates, C. Boyer, and O.G. Almeida*. 2024. Inclusion of cool and warm-season species to tall fescue swards for increased productivity. Agronomy Journal. doi.org/10.1002/agj2.21690

Corbin, M.D.*, R.L.G. Nave, H. Naumann, G. E. Bates, C. Boyer, and O.G. Almeida*. 2024. Does adding legumes to tall fescue pastures before stockpiling improve productivity and animal performance? Agronomy Journal. doi.org/10.1002/agj2.21676

Proceedings and Scientific Abstracts

Furlan Junior, R., T. C. Mueller, L. E. Steckel, R.L.G. Nave, and B. Pedreira. 2024. Evaluating alfalfa establishment when controlling glyphosate-resistant Palmer Amaranth with soil fertility and herbicide application. Beef and Forage Center Annual Research Report.

Furlan Junior, R., T. C. Mueller, L. E. Steckel, R.L.G. Nave, and B. Pedreira. 2024. Bringing alfalfa back to Tennessee: Importance of fall weed control on spring forage accumulation. Beef and Forage Center Annual Research Report.

Almeida, O.G., R.L.G. Nave, M.D. Corbin, M.A.S. Malheiros, F. Nassar, V. Martinez, Y. Roberts, and R. C. Silva. 2024. Agronomic Responses in Tall Fescue Swards Mixed with Legume Species. International Annual Meetings ASA-CSSA-SSSA – San Antonio, TX.

Lima, C.E., Nassar, F.F., D. McIntosh, Reis, R.A., R.L.G. Nave, and B. Pedreira. 2024. Evaluating Azospirillum brasilense inoculation and nitrogen management on crabgrass. International Annual Meetings ASA-CSSA-SSSA – San Antonio/TX.

Malheiros, M.A.S.*, R.L.G. Nave, Nassar, F., and Dillard, S.L. 2024. Effects of the Application of Plant Growth Promoting Rhizobacteria in the Production of Bermudagrass (Cynodon Dactylon) in Tennessee, United States. International Annual Meetings ASA-CSSA-SSSA – San Antonio/TX.

Martinez, V., R.L.G. Nave, Almeida, O.G., V. R. Sykes, B. Pedreira, and C. Boyer. 2024. Optimizing organic corn production under different living mulch systems. International Annual Meetings ASA-CSSA-SSSA – San Antonio/TX.

Nassar, F.F., R.L.G. Nave, Dillard, S.L., B. Pedreira, Silva R.C., Malheiros, M.A.S., Martinez, V., Roberts, Y., and Almeida, O.G. 2024. Use of plant growing-promoting bacteria as an alternative fertilizer for bermudagrass. International Annual Meetings ASA-CSSA-SSSA – San Antonio/TX.

Roberts, Y.*, R.L.G. Nave, V. R. Sykes, K. J. Walters, A. P. Griffith, and Almeida, O.G. 2024. Management and Productivity of Corn and Alfalfa Intercropping Systems in the Southern U.S. International Annual Meetings ASA-CSSA-SSSA – San Antonio/TX.

Silva R.C., R.L.G. Nave, Dillard, S.L., B. Pedreira, Nassar, F.F., Malheiros, M.A.S., Martinez,

V., Roberts, Y., and Almeida, O.G. 2024. Qualitative and productive effects of plant growth-promoting bacteria (PGPB) in tall fescue. International Annual Meetings ASA-CSSA-SSSA – San Antonio/TX.

Texas
Texas A&M AgriLife Research – Beeville Station (Foster)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

The Forage Management Program led by Jamie Foster at Texas A&M AgriLife Research – Beeville Station is focused on systems research with the goal of enhancing resource use efficiency. Resource use efficiency can be improved through management, including integrating legumes or agricultural co-products into animal, food, and fiber systems. This research has resulted in greater adoption of conservation agriculture in the south Texas region.

1. New Facilities and Equipment
LiCor Smart Chamber and GasMet

2. Unique Project Related Findings
A project to evaluate the impact of variable rate irrigation on alfalfa production in south Texas, where alfalfa is not a common commodity, continued with an expanded location in Beeville. Work to quantify soil carbon in row crop versus grassland systems in Texas is still underway with funding from several commodity boards. A new project on conversion of crop land to perennial forage systems is being initiated as is a project with reclaimed frac water for irrigation in West Texas.

A project evaluating the use of native grasses and forbs for bioenergy was completed. This results in an additional use for rangelands or fields planted to native species, thereby, reducing investment risks. Industry funding continued for an evaluation of perennial rhizomatous crops and torrefied biomass amendment for bioproduct production. Additionally, energycane grown with cool-season legume was planted to determine the impacts of intercropping on carbon and water cycling. Two long-term cropping systems continued: 1) the first is cotton and sorghum rotation managed with either no-tillage or full tillage 2) the second is annual cotton-sorghum rotation with no-tillage, tillage, cover crops, and sorghum residue retention as replicated treatments.

The cattle herd at Beeville Station was rebuilt to include sensors for GPS location and ruminal temperature. Integration of forage spatial distribution data and forage system evaluation is in development. Work on UAS-derived phenotypic parameters to develop an artificial neural network to estimate herbage mass and carbon content continues. Collaboration on ‘Fostering resilience and ecosystem services in landscapes by integrating diverse perennial circular systems (F-RESILIENCE)’ an AFRI: Sustainable Agriculture Systems Coordinated Agricultural Project continues. Participation in coordinating meetings and data has been sent to the development of Forage Data Hub and Forage Information System.

3. Accomplishment Summaries
Published data on variety of forage and cropping systems agronomic research topics. Outreach activities included the delivery of findings during in-service training sessions, field days, and through various extension publications.

4. Impact Statement
Issue: Warm-season grass establishment in semiarid environments is expensive and not always successful.

Action: Research project evaluating the use of introduced and native grasses for flexibility of bioenergy or forage was conducted.

Impact: Flexibility in uses of warm-season grasses increases the profitability of establishment by landowners. Targeted information on species suitability on a regional scale.

Contact:

Jamie L. Foster, Texas A&M AgriLife Research-Beeville Station

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Funding:

This project was conducted with appropriations from the South Central Sun Grant Regional Program (USDA) and Texas A&M AgriLife Research.

5. Published Written Works

Book/Journal Issue

Nothing to report.

Book Chapters

Nothing to report.

Refereed Journal Articles

1. Ashworth, A.J., A. Tyson, T. Propst, L. Marshall, J.J. Volenec, M.T. Berti, E. van Santen, V. Picasso, J.L. Foster, and J. Su. 2025. Knowledge graph applications for identifying climate-smart forage systems. Ag. Enviro. Letters. 10:e70021. doi: 10.1002/ael2.70021

2. Muir, J. P., J. C. Dubeux, M. V. Ferreira dos Santos, J.L. Foster, R. L. Caraciolo Ferreira, M. A. Lira, B. Bellows, E. Osei, B. B. Singh, and J. Brady. 2025. Sustainable forage legumes: versatile products and services are key. Grasses. 4:16. doi: 10.3390/grasses4020016

3. Victoria, M., H.R. Leggette, J.L. Foster, M.L. Orem, C. Neely, H.L. Neely, and K. Palmer. 2025. Exploring wheat farmers' soil health management practices, adoption characteristics, and information preferences. J of Appl. Comm. 109:1-23. doi: 10.4148/1051-0834.2554

4. Ghansah, B., J.L. Landivar Scott, L. Zhao, M.J. Starek, J.L. Foster, J. Landivar, and M. Bhandari. 2025. Satellite vs uncrewed aerial systems (UAS): Comparing high-resolution SkySat and UAS images for cotton yield estimation. Computers and Electronics in Ag. 234: 110280. doi: 10.1016/j.compag.2025.110280

5. Khuimphukhieo, I., B. Ghansah, L. Zhao, J. L. Landivar Scott, O. Fernández Montero, J. Da Silva, H. Li, J. Foster, and M. Bhandari. 2025. Use of uncrewed aerial systems (UAS) based – crop features to perform growth analysis of energy cane genotypes. Plants. 14:654. doi: 10.3390/plants14050654.

6. Orem, M., H. Leggette, J.A. Parrella, P. Lu, K. Palmer, J.L. Foster, H. Neely, and R. Noland. 2024. Harvesting trust: Exploring credible information sources about soil health practices for U.S. wheat farmers. Journal of Applied Communications. doi: 10.4148/1051-0834.2553

7. Foster, J.L., M.K. Clayton, M.M. Lesak, K. McCuistion, and T. Teinert. 2024. Combining management techniques for short-term reduction of introduced old world bluestems in south Texas rangelands. Rangeland Ecology and Management. doi: 10.1016/j.rama.2024.12.001

8. Reemts, C., J. Havird, W. Behr, M. Clayton, J.L. Foster, M. Lesak, C. Whiting, C. Farrior, and A. Wolf. 2024. Fire season and drought influence fire effects on invasive grass: a meta-analysis. J. App. Ecol. 62: 1296–1308. doi: 10.5061/dryad.xpnvx0ks4

Symposium Proceedings

Nothing to report.

Abstracts

1. Haces-Garcia, J., H. Li, J. da Silva, M. Bhandari, and J.L. Foster. 2025. Life cycle assessment of ethanol production using various energy canes as biomass crops. Institute of Industrial and Systems Engineers (IISE) Annual Conference, Atlanta, GA, May 21-Jun 3. (Abstr.)

2. Shadrock, C.A., O.Lasater, J.P. Muir, J.L. Foster, and A.D. Falk. 2025. Climate & market-flexible, multiple-use native grassland species. Society for Range Management 2025 Annual Meeting, Spokane, WA, Feb 9-13. (Abstr.)

3. Orem, M., H. Leggette, J. Parrella, P. Lu, K. Palmer, J.L. Foster, H. Neely, and R. Noland. 2025. Digging into soil health: Farmers' perspectives on climate-smart practices. American Association for Agricultural Education Southern Region Conference, Irving, TX, Jan. 30-Feb 4. (Abstr.)

4. Foster, J.L., M. Bhandari, L. Goldsmith, O. Fernandez, J. Landivar Scott, Y. Calil, D. Min, G. Jha, J. Aguilar, S. Dey, and J. Kim. 2024. Application of UAV technology to improve irrigation efficiency in alfalfa. ASA-CSSA-SSSA 2024 International Meetings, San Antonio, TX, Nov. 10-13. (Abstr.)

5. Ghansah, B., M. Bhandari, J. Landivar Scott, M. Starek, J.L. Foster, and J.A. Landivar. 2024. Very high-resolution crop canopy height estimation using Icesat-2, Skysat images, and deep convolutional neural network (CNN). ASA-CSSA-SSSA 2024 International Meetings, San Antonio, TX, Nov. 10-13. (Abstr.)

6. S. Sarkar, Ghansah, B., I. Khuimphukhieo, J. Landivar Scott, O. Fernandez, M. Starek, J.L. Foster, J. DaSilva, H. Li, and M. Bhandari. 2024. High-throughput estimation of above-ground biomass of energycane using aerial RGB images. ASA-CSSA-SSSA 2024 International Meetings, San Antonio, TX, Nov. 10-13. (Abstr.)

7. Zamora, E., S. Dattamudi, D. Sanyal, G. Schuster, J. McGinty, S.V. Gopinaresh Vurranki, and J.L. Foster. 2024. Effect of cover crop mixtures and tillage practices on soil health and agricultural sustainability in a long-term research field. ASA-CSSA-SSSA 2024 International Meetings, San Antonio, TX, Nov. 10-13. (Abstr.)

8. Bekele, A., B. Jaffe, G. Pilloni, T. Barckholtz, M. Higgins, R. Jessup, J.L. Foster, R. Noland, and C.L. Trostle. 2024. Torrefied mesquite soil amendment and perennial crops for marginal land restoration. ASA-CSSA-SSSA 2024 International Meetings, San Antonio, TX, Nov. 10-13. (Abstr.)

9. Reemts, C., M. Lesak, M. Clayton, J.L. Foster, and C. Whiting. 2024. Fire season and drought influence fire effects on invasive grass: a meta-analysis. Texas Society for Ecological Restoration 27th Annual Conference, Houston, TX, Nov. 7-9. (Abstr.)

10. Valencia, H., K.L. Lewis, J.L. Foster. 2024. Simultaneous determination of β-glucosidase, β-glucosaminidase, acid phosphatase, and arylsulfatase in double cropping wheat agroecosystems across Texas. Soil and Water Conservation Society International Annual Conference, Myrtle Beach, SC, Jul. 21-24. (Abstr.)

11. Ghansah, B., I. Khuimphukhieo, J.L. Landivar Scott, M. Bhandari, M.J. Starek, J.L. Foster, J. Da Silva, and H. Li. 2024. Utilizing UAS-Lidar for high throughput phenotyping of energy cane. IEEE International Geoscience and Remote Sensing Symposium. Athens, Greece, Jul. 7-12. (Abstr.)

12. Ghansah, B., L. Zhao, M. Bhandari, J.L. Landivar Scott, M.J. Starek, J.L. Foster, and J. Landivar. 2024. How to improve cotton yield estimation at high spatiotemporal resolution by fusing ICESat-2 and SkySat with deep learning. 2024 AI in Agriculture and Natural Resources Conference, College Station, TX, Apr. 15-17. (Abstr.)

13. Rodriguez, K.A., J.L. Foster, M. Bhandari, and N.L. Mast. 2024. Drought resilient alfalfa production using digital agriculture and machine learning techniques. LEADING Hispanics Symposium and Career Fair, Texas A&M University-Kingsville, Kingsville, TX, Feb. 12. (Abstr.)

14. Orem, M., H. Leggette, D.M. Wald, R. Noland, K. Palmer, E. Fuller, L. Baker, and J.L. Foster. 2024. Determining information sources wheat producers perceive as scientists. American Association for Agricultural Education Southern Region Conference, Atlanta, GA, Feb. 4-6. (Abstr.)

Extension Publications

Nothing to report.

Popular Articles

1. Ellis-Ashburn, H. and J.L. Foster. 2024. Forage for your horse. Western Horseman. Oct. 2024. Vol. 89(6):35-38.

6. Scientific Outreach Presentations

1. J.L. Foster. Forage Nexus Podcast. Grazing Along talk series for National Forage Week. New technologies on forage management -from research into practice. June 15-21, 2025.

2. J.L. Foster. Long-term conservation agriculture research in south Texas. Soil Health, Cover Cropping and Long-Term Research in South Texas Tour. Agronomy Society of America, Soil Health Community, Corpus Christi, TX. Nov. 9, 2024.

3. J.L. Foster. South Texas Forages Tour. Southern Pasture Forage Crop Improvement Conference. Corpus Christi, TX, Apr. 22, 2025.

4. J.L. Foster. Experts and stakeholders conference on the threats to the U.S. Beef Supply Chain. Cross-Border Threat Screening and Supply Chain Defense Center. Invited Panel Member. Oct. 21-23, 2024.

5. J.L. Foster. Forage and Beef Production Systems for South Texas. Texas A&M

University College of Agriculture and Life Sciences Development Committee. Corpus Christi, TX. April 24, 2025.

6. J.L. Foster. Herbicide efficacy measured by drones. South Texas Beef and Forage Field Day. Texas A&M AgriLife Extension of Atascosa, Bee, Goliad, Jim Wells, Karnes, Live Oak, McMullen, Nueces, Refugio, and San Patricio Counties and Corpus Christi based Extension Specialists, Beeville, TX. April 30, 2025.

7. J.L. Foster. Winter overseeding (cover cropping) options for south Texas. Pesticide Applicator CEU Training – Livestock Producers, Texas A&M AgriLife Extension of Dimmit, Frio, Uvalde, and Zavala Counties, Uvalde, TX. Dec 10, 2024.

8. J.L. Foster. Forages for sustainable agriculture in south Texas. Texas A&M University-Kingsville, Graduate Seminar in Environmental Engineering, Virtual. Nov 8, 2024.

9. J.L. Foster. Improving soil health with conservation cropping in south Texas. Texas A&M AgriLife Research and Extension Center at Corpus Christi 50th anniversary field day. May 23, 2024.

10. Foster, J.L., J. McGinty, and M. Bhandari. Farming and ranching for the future. Texas A&M AgriLife Research and Extension Center at Corpus Christi 50th anniversary field day. May 23, 2024.

11. J.L. Foster. Texas A&M AgriLife Research - Beeville Station Est. 1894. Texas A&M AgriLife Research and Extension Center at Corpus Christi 50th anniversary field day. May 23, 2024. (poster)

12. J.L. Foster. Linking carbon and water to forage production. South Texas Beef and Forage Field Day. Texas A&M AgriLife Extension of Atascosa, Bee, Goliad, Jim Wells, Karnes, Live Oak, McMullen, Nueces, Refugio, and San Patricio Counties and Corpus Christi based Extension Specialists, Beeville, TX. May 8, 2024.

13. J.L. Foster. Agronomy and Plant Sciences. Windsor Park Elementary School, Corpus Christi, TX, Feb. 14, 2024.

7. Disclosures/Patents

Nothing to report.

8. Collaborative Grants between Stations and Members Awarded

Lewis, K., J. Goodwin, J.L. Foster, P. DeLaune, M. Hussey, J. Muir, Nuria Gomez-Casanovas, J. Burke, C. Cobos, T. Gentry, S. Ale, W. Keeling, A. Wright. 2023. Regenerative agriculture using treated produced water. WaterBridge. 2024-2029. Co-Investigator. $4,339,143; $597,503 for program.

Lewis, K., C. Bednarz, F. Abello, J. Foster, J. Burke, A.P. Wright, P. DeLaune, and S. Ale. 2024. Row crops to perennial pasture: Feeding the world, conserving water, enhancing soil, and safeguarding the climate. Foundation for Food and Agricultural Research Seeding Solutions. 2024-2028. $1,992,330. Co-Investigator.

9. Graduate Students

Name, MS/PhD, graduation date/expected graduation date, thesis title

Shishir Sapkota, Ph.D., Texas A&M University-College Station, 2025-2027. Grassland remote assessment.

Ernesto Reyes, M.S., Texas A&M University-Corpus Christi, 2025-2027.
Integration of animal and plant sensors for grassland assessment.

Utah
Utah State University (MacAdam)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

As part of the Smart Foodscapes Sustainable Agriculture Systems NIFA grant, we have assessed more than 20 native and introduced legumes and forbs that are used as forage by cowherds grazing rangeland. Criteria included the ability to become established in dense stands, to provide significant dry matter yield, to persist without irrigation, to provide supplemental levels of protein and total digestible nutrients to support gestation, and for the value of of their accumulated secondary metabolites to support animal health and benefit the environment. The plant species with the greatest promise are sainfoin, alfalfa (both *Medicago sativa* and *M. sativa* ssp. *falcata*), birdsfoot trefoil, cicer milkvetch, Maximillian sunflower, sainfoin, showy goldeneye, small burnet, and Utah sweetvetch.

2. New Facilities and Equipment

Shimadzu 2030 gas chromatograph with an AOC-6000 Plus autosampler configured to detect greenhouse gases (CH_4, N_2O, CO_2) as well as SF_6 for analysis of exhaled enteric gases from rangeland or pastured ruminants.

3. Unique Project Related Findings

4. Accomplishment Summaries

In her report, Dr. MacAdam discussed the provision of crude protein and total digestible nutrients in the quantities of dry matter intake required by beef cows in the early stages of gestation.

5. Impact Statements

6. Published Written Works

Refereed publications

Ates*, S. E. Seeno, J. MacAdam, and D. Moot. 2025. Exploring clover-based nurse cropping for birdsfoot trefoil establishment and yield. *Grass and Forage Science* 80: e12710.

MacAdam*, J.W., J. Gibbons, and X. Dai. 2025. Weed incursion of irrigated forage-forb mixtures under mob grazing or mowing in the Mountain West USA. *Agronomy*, **15010025**.

MacAdam*, J.W., B. Maughan, and X. Dai. 2025. Production, utilization and quality of irrigated grasses and legumes in the Mountain West USA under mob stocking or mowing at the same defoliation frequency and intensity. *Grassland Research* 4: 31–40.

MacAdam*, J.W.; J.J. Villalba; S. Lagrange; E.K. Stewart, L.R. Pitcher, K.A.Slebodnik, J.M. Norton, J.R. Reeve, Y. Zhang, A.I. Bolletta, J.F. Legako, R.G. Christensen, and S.R.

Hunt. 2025. Beneficial effects of perennial legume and forb functional forages in the Mountain West U.S.A. *Grass and Forage Science,* 80: e12719

Gregorini*, P., and Villalba, J.J. 2024. Modelling the effect of grazing management of tannin-containing legume feeding sites on environmental impact by cows grazing grass-dominated rangelands. *The Journal of Agricultural Science*. 163: 202–211.

Sakhraoui*, A., Ltaeif, H.B., Sakhraoui, A., Villalba, J.J., Castillo, J.M., Rouz, S. 2024. Sainfoin (*Onobrychis viciifolia*) a legume with great ecological and agronomical potential under climate change. *The Journal of Agricultural Science*. 162: 307–331.

Terra-Braga M., Poli, C.H., Tontini, J.F., Ahsin, M., Van Vliet, S., Villalba*, J.J. 2024. Trade-offs between selection of crude protein and tannins in growing lambs. *Journal of Animal Science* 102:skae298.

Villalba, J. J., R.D. Ramsey, and S. Athanasiadou. 2024. Herbivory and the power of phytochemical diversity on animal health. *Animal*, 2024.101287.

Proceedings publication

Villalba*, J.J.; MacAdam, J.W., Ramsey, D., Batistel, F., Thacker, E., Dahlgren, D., Palmer, M., Schad, J. Creating new foodscapes to enhance the sustainability of rangelands in the Western US. Proceedings of the International Rangeland Congress, 2-6 June 2025, Adelaide, Australia.

8. Collaborative Grants

NIFA Sustainable Agriculture Systems CAP Grant, 10/01/21 to 09/30/26. Using smart foodscapes to enhance the sustainability of western rangelands. PD J.J.Villalba; multiple Co-PDs including J.W. MacAdam, $6,800,000.

9. Graduate students

Ph.D.

Zubair Barkat

Iddy Muzzo

Master's

Horacio Blanchard

Taylor Jackson

Prakriti Paudel

Sebastian Schreiber-Pan

Surbhi Verma

Wisconsin
University of Wisconsin – Madison (Kohmann)
NCCC-31 Ecophysiological Aspects of Forage Management
2024-2025

1. Impact Nugget

The forage group from University of Wisconsin-Madison is working on various efforts:
[1] Nutrient cycling and nutrient credits from alfalfa termination in Spring or Fall with and without manure application;
[2] Wheel traffic effects on alfalfa-corn interseeded systems;
[3] Breeding cover crops for forage systems; and
[4] Managing allelopathic cereal rye in grain and forage systems.

2. New Facilities and Equipment

None.

3. Unique Project-Related Findings

[1] Plant litter decomposition rate is greater for above- than for belowground biomass, while manure application causes a lag in plant litter decomposition;
[2] When alfalfa was trafficked by trucks, they showed lower % cover than when it received no traffic. However, Fall stem count was similar across treatments. In the spring, truck-trafficked alfalfa plots had lower stem count levels compared to the no traffic control.
[3] There are divergent characteristics on cereal rye genetic material, so that breeding efforts for use of cereal rye as a cover crop can be targeted to forage or to grain systems accordingly;
[4] Allelopathic cereal rye, terminated the same day as cash crop planting, seems to reduce alfalfa but not corn germination.

4. Accomplishment Summaries

During 2024-2025, two projects were initiated:
[1] A litterbag decomposition study, investigating nutrient mineralization from various cover crops terminated at two different dates;
[2] A greenhouse study evaluating the effect of traffic on alfalfa crown, soil, alfalfa plus soil, and control (no traffic).

5. Impact Statement

[1] Litterbag study: Initial results indicate cover crops terminated at flag leaf stage show greater initial decomposition than those terminated at heading stage, but in both cases, nutrient net immobilization occurs;
[2] Wheel traffic on alfalfa crown is more detrimental than the soil compaction resulting from wheel traffic. Damage occurs to aboveground biomass (-20% relative to control) and, to a greater degree, to the belowground biomass (-25% relative to control).

6. Published Written Works (selected peer-reviewed and outreach-oriented)

Refereed publications

Cardoso, A.S., M.L. Silveira, M.M. Kohmann, J.M.B. Vendramini, J.M.D. Sanchez, N. Ghimire, R. Bracho. Prescribed fire effects on vegetation responses in subtropical rangelands. Rangelands (In print). doi: 10.1016/j.rala.2025.05.001

Shaheb, M.R., J.H. Grabber, M.M. Kohmann, Mark J. Renz. Yellow foxtail [*Setaria pumila* (Poir.)] reduces alfalfa establishment in interseeded corn silage and alfalfa systems. Weed Science73(e36), 1-6. doi: 10.1017/wsc.2025.9

Vieira-Filho, L.O., M.L. Silveira, J.M.D. Sanchez, M.M. Kohmann, E. Ricken. 2025. Environmental impacts of land application of biosolids to perennial pastures. Journal of Environmental Quality 54, 246-256. doi: 10.1002/jeq2.20664

Outreach publications

1. Smith, D., Blackburn, A., Kohmann, M., Renz, M., and Werle, R. 2025. Herbicide Rotational Restrictions, Weed Control, and Cereal Rye for Forage. In: Crops and Soils Extension. Available in: https://cropsandsoils.extension.wisc.edu/articles/herbicide-rotational-restrictions-weed-control-and-cereal-rye-for-forage/
2. Kester, K., Bill Halfman, and Marta Kohmann. Swath grazing as an alternative for beef cattle. Forage Focus, Grazing Section. Midwest Forage Association, June Issue.

7. Scientific and Outreach Presentations

Scientific

1. Bizzuti, B.E. (presenter), P. Williams, M.M. Kohmann, F.J. Arriaga, D.W. Hancock, B. Luck. 2024. Effects of Machinery Traffic on Alfalfa Forage Harvested. In ASA, CSSA, SSSA International Annual Meeting. San Antonio, TX. Poster.
2. Cardoso, A.S. (presenter), C.C. Nieman, J.G. Franco, M.M. Kohmann. 2024. Implications of organic cover crop termination strategies on cash crop population counts and weed canopy in the mid-South. In ASA, CSSA, SSSA International Annual Meeting. San Antonio, TX. Poster.
3. Cardoso, A.S. (presenter), J.G. Franco, C.C. Nieman, M.M. Kohmann, M.A. Liebig, J.R. Hendrickson, S.L. Kronberg, A.K. Clemensen, D.W. Archer. 2024. Soil benefits of objective-based cover crop mixtures and grazing during organic transition in the northern Great Plains. In ASA, CSSA, SSSA International Annual Meeting. San Antonio, TX. Poster.
4. Costa, M. (presenter), J. Grabber, M.M. Kohmann, W. Osterholz, E. Burns, J.L.C.S. Dias, M.J. Renz. 2024. Improving Alfalfa Establishment When Interseeding into Corn with on-Farm and Controlled Field Research. In ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX.
5. Franco, A. (presenter), M.M. Kohmann, M.J. Renz, D.M. Jaramillo. 2024. Do increased stocking periods affect animal performance and weed population in southern Wisconsin? In ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX.

6. Franco, A. (presenter), M.M. Kohmann, M.J. Renz. 2024. Evaluating the carryover of corn residual herbicides containing clopyralid on alfalfa establishment and productivity. In North Central Weed Science Society Meeting. Kansas City, MO. Poster.
7. Ghimire, N. (presenter), M.L. Silveira, J.M.B. Vendramini, P. Moriel, M.M. Kohmann, A.D.S. Cardoso, P.J.R. da Cruz, J.A. Bernal, N.R. Kovvuri. 2024. Stocking rate effects on greenhouse gas emissions from subtropical pastures. In ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX.
8. Renz, M.J. (presenter), MD.R. Shaheb, M.M. Kohmann, J. Grabber. 2024. Yellow foxtail [*Setaria pumila* (Poir.)] reduces establishment of alfalfa interseeded into corn. In North Central Weed Science Society Meeting. Kansas City, MO. Oral.
9. Jaramillo, D. (presenter), A. Franco, M. Kohmann, M. Renz. 2025. Effect of stocking period on pasture species composition, forage production, and animal performance. In 2025 American Forage & Grassland Council. Orlando, FL. Oral presentation.
10. Robbins, F. (presenter), E. Bick, L. Flandermeyer, Marta Kohmann. 2025. Quantifying weather and circadian influences on insect catchability for improved IPM. In 2025 North Central Branch Meeting, Entomological Society of America. Lincoln, NE. Oral presentation.

Outreach
1. Marta Kohmann. What is New in Alfalfa Production Systems? Event: World Dairy Expo. Date: 3 October 2024. Type: Face-to-face. Location: Madison, WI. Participants: 25 in person; also available online on World Dairy Analysis Superbowl channel (https://www.youtube.com/@worldforageanalysissuperbo2233; 105 subscribers). Also listed at "Invited Extension Presentations".
2. Marta Kohmann. Title: Alfalfa in integrated systems. Event: 2025 Wisconsin Agribusiness Classic. Location: Wisconsin Dells, WI. Date: 14 January 2025. Type of contact: Face-to-face. Participants: 72.
3. Marta Kohmann. Title: Managing pasture for persistence. Event: Driftless region beef conference Location: Dubuque, Iowa. Date: 23 January 2025. Type of contact: Face-to-face. Participants: 150.
4. Marta Kohmann. Title: Pasture management for cow-calf operations. Event: Driftless region beef conference Location: Dubuque, Iowa. Date: 24 January 2025. Type of contact: Face-to-face. Participants: 70.
5. Arthur Franco, Lais Lima, Carlos Camisa Nova, David Jaramillo, and Marta Kohmann. Title: Updates in grazing research. Event: GrassWorks Grazing Conference. Location: Wisconsin Dells. Date: 25 January 2025. Type of contact: Face-to-face. Participants: 60.
6. Marta Kohmann. Title: Basic Principles of Forage Management. Badger Crops Club. Date: 7 February 2025. Type of contact: Face-to-face. Location: Madison, WI. Participants: 18.
7. Lisa Kissing Kucek and Marta Kohmann. Forage cover crops for dairy rotations: Variety selection & improvement. Midwest Forage Association Symposium. Location: Wisconsin Dells, WI. Date: 19 February 2025. Type of contact: Face-to-face. Participants: 60.

8. Graduate Students

Ph.D.:

Jasmin Buffen. Graduation date May 2028. Breeding efforts for improved cover crop management in the Upper Midwest.

Arthur Teodoro Duarte Franco. Graduation August 2028. Ceral rye allelopathy in corn grain systems.

M.Sc.:

Colin Van De Loo. Graduation date May 2027. Cereal rye allelopathy in alfalfa systems.