**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 2023 to August 2024

**Date of This Report:** October 03, 2024

**Annual Meeting Date(s)**: Fargo, ND, August 12-14, 2024

**Brief summary of minutes of annual meeting:**

**President:** Dr. Marília B. Chiavegato (Ohio)

**Secretary:** Dr. Marta Moura Kohmann (Wisconsin)

**Host:** Dr. Marisol Berti (North Dakota)

**Participants (PIs):** 22, representing 12 states

Peter Ballerstedt (PA) | Marisol Berti (ND) | Kim Cassida (MI) | Barney Geddes (ND) | Kendra Greenle (ND) | Amada Grev (MD) | Shelby Gruss (IA) | John Guretzky (NE) | David Hannaway (OR) | Richard Horsley (ND, Chair of Department of Plant Sciences) | Gordon Jones (OR) | Jim Kells (MI - Admin Advisor) | Bill Lamp (MD) | Jennifer McAdam (UT) | Miranda Neehan (ND) | Marta Moura Kohmann (WI) | Renata Oakes (TN) | Dirk Phillip (AR) | Valentin Picasso (WI - online) | Juan Romero (ME) | Robert Salermo (MD) | Guojie Wang (PA) | Carol Williams (WI)

**Participants (graduate students):** 10, representing 3 states

Angad Dhariwal (WI) | Kayla Ehlis (ND) | Alexandre Mammana (OH) | Emanuel Dall’Agnol (FL) | Miguel Grijalba (ND) | Houston Lindell (ND) | Ogechukwu Igboke (ND) | Md. Shazzadul Islam (ND) | Miranda Meehan (ND) | Franklyn Omeye (ND)

**Participants (postdoctoral scientists):** 1, representing 1 state

Priscila Pinto (WI)

**Activities:**

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**Business meeting minutes**

1. Nominations for hosting: Shelby Gruss put in a motion for having the meeting in Tennessee. Dirk Philipp seconded. Renata Oakes indicated that timing might be important– early June was suggested as a better time due to the heat. Motion passed.
2. Nominations for secretary: Shelby Gruss was nominated by Marisol Berti. Dirk Philipp makes a motion in support, Renata Oakes seconds. Motion passes.
3. Peter Ballerstedt indicated that the first full week of June is the international rangeland congress in Adelaide, Australia. We will look into June dates that avoid the time conflict.
4. Renewal: Discussion about renewal of the NCCC31 (Ecophisiology Aspects of Forages Management) project.
   1. Last Spring, an email was sent to official member about the interest in renewal.
   2. The point person for renovation will be Bill Lamp. Bill Lamp also led the discussion about the renewal.
   3. Project title: will remain the same.
   4. Objectives: will remain the same, and we are currently not planning on changing the objectives.
   5. What projects might group participants work on in the future? Word cloud indicates management (nutrient, variety, species choice) are most important themes. Integration of animals comes up as well, which can be challenging as the NCCC31 group has been traditionally kept separated from animals. Other important themes are ecosystem and resilience.
   6. Management theme includes: prairie restoration, cover crops, soil health, winter hardiness for alfalfa.
   7. Ecosystem theme includes: impact of climate, evaluation of animal health, beneficial biodiversity, GHG emissions. seems to agree with RFA.
   8. Animal science theme includes: grazing, animal nutrition
   9. Other: research, teaching, and extension: opportunity to create course and course materials.
   10. The group agrees on the importance of continuing to integrate research, teaching, and extension.
   11. Membership: USDA can join by contacting NCCC office directly. Extension educators are eligible case-by-case.
   12. Timeline
       1. 15 September: request renew committee
       2. Between 15 September – 15 October – upload issues and justification
       3. 15 October: upload the objectives. After this, everyone has to rejoin the system
       4. By December 1st, proposal must be submitted
   13. Content questions and discussion
       1. Stakeholder involvement: input from the stakeholder is not in the language, but there is an expectation of stakeholder involvement.
       2. Each AES needs to define the objective you plan to wrk on/contribute to.
       3. Previous proposal: the group used to send their annual reports in advance (before the in-person annual meeting), but that was abandoned during the pandemic. There will be one template for all state reports in 30 days after the meeting so that the secretary has time to submit the final report.
       4. Discussion: How will we work together to identify new funding sources on research or teaching grants? Internship grant will be added. Expansion of RCAP to other grants. After RCAP ends, we will do some continuation (Picasso)? Juan suggested PFAS survey? Guojing suggested brainstorming for 30 min to get new ideas.
   14. Writing committee: we must establish it this year. Mark Sulc used to run this, and when leading the committee, he would always share its progress with the whole group setting the example for what we plan to continue doing. Current committee (lead by Bill Lamp) is composed by: Juan Romero, Amanda Grev, Shelby Gruss, Dirk Philipp, Marisol Berti.
   15. At renewal, the default is that we will continue as a coordinating committee. This will only change if we change the objectives to a point that will be interpreted by reviewers as better fit to a different group. Bill Lamp raised the question that we could/should include animals in Objective 2 (“physiological and ecological aspects…”). We need to search for other committees to see if there is any other committee that has overlap. There is one other committee with nutrient soil and one on forage production with a focus on animals). They are both active (#1181 and 1182).
   16. Peter asked for order. Picasso motions to end business meeting; Peter seconds, all say I. Motion passes.

**STATE REPORTS**

**NCCC31- Ecophysiological Aspects of Forage Management, 2024 Report**

**Arkansas Report 2023-2024**

**University of Arkansas, Animal Science Department**

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. Our current activities, based on external funding, focus on determining nitrogen fluxes at the soil-plant-animal interface, soil water retention under grazing to different canopy heights, forage establishment and growth in wooded areas, and prairie reconstruction for roadside management.

1. **New Facilities and Equipment**

ATV, tractor GPS unit

1. **Unique Project-Related Findings**

We finished a sheep grazing project that had the objective to determine the effect of canopy defoliation on soil water status. This project was comprised of stocking 0.25-acre paddocks with ~30 grown ewes and defoliating forage to ~50% or ~85% of forage mass measured pre-stocking. Included control paddocks were not stocked. Water measurements were being accomplished by taking soil samples and collecting data from permanently installed soil sensors. Preliminary data analyses suggested there were no clear grazing effects observable and that non-grazed plots may even result in lesser soil water content due to an increased transpiration from a larger leaf area than in fully grazed plots.

A small-plot, prairie restoration experiment started several years was adjusted after initial failure in 2021/2022. We were able to establish a very 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.

1. **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)
   1. Data currently being evaluated and analyzed
2. AR DOT Roadside project, (continued and extended)
   1. Extended into planting-date experiments and nurse crop trial
3. Establishment of savannah-type ecosystems (started)
   1. Ground preparation (tillage) for native grass establishment and tree cover completed
   2. Assessment of tree species and number/acre are underway
      1. Southern red oak, white oak, and burr oak are being considered
4. Continued cooperation on agroforestry project spearheaded by USDA-ARS Ames, IA
   1. Site preparation for native grass planting in spring of 2025
      1. Repeated herbicide application
   2. Tree thinning

**Impact Statement**

**Issue:**

Forage-based production systems dominate production of meat and milk but are inefficient in terms of feed conversion and nitrogen use efficiency. Besides carbondioxide and methan, nitrous oxide is a very potent greenhouse gas resulting from ruminat enteric emissions and losses from soil through various processes including manure deposition. Reducing overall nitrous oxide emissions and balancing nitrogen in feed will lead to reduced environmental impacts while increasing feed conversion efficiency.

**Action:**

We secured funding for 5 years (2018 – 2023) to feed sheep with high- and low-tanning containing alfalfa/lespedeza silages as those will affect the amount of nitrogen converted in the rumen vs. bypass protein for digestion in the lower gut. Feces and urine were collected while 80 field plots were established in an existing tall fescue pasture to measure nitrous oxide, methane, carbon dioxide, and ammonia emissions and measuring nitrate leaching in soil cores of different diameters to which urine and a slurry of urine and feces that were applied in two different experiments in fall of 2018 and spring/summer 2019. Over the past several years, we conducted experiments on soil nitrate leaching, microbial activity, and ammonia emissions after the application of sheep urine and feces on various native and non-native perennial forages. We conducted a detailed greenhouse study using 100+ soil cores to determine leaching dynamics from the application of sheep urine. This project was concluded in summer of 2023.

**Impact:**

These studies will lead to a more efficient use of natural resources and farm inputs. A potential improvement of nitrogen use efficiency and feed conversion efficiency will help in using natural resources more efficiently as well. Research progress and updates will be communicated throughout the duration of the experiments through appropriate media outlets.

**Contact:**

Dirk Philipp, Department of Animal Science

479/575-7914 / [dphilipp@uark.edu](mailto:dphilipp@uark.edu)

Cooperators: **M. Savin, K. Coffey, and R. Rhein**

**Funding:**

This project was conducted with appropriations USDA-NIFA and from the University of Arkansas – Division of Agriculture/Agricultural Experiment Station.

1. **Published Written Works**

*Peer-reviewed:*

**Amorim, H.C.S.**, A. J. Ashworth, P.L. O’Brien, A.L. Thomas, **B.R.K. Runkle, and D. Philipp**. (2023). Temperate silvopasture provide greater ecosystem services than conventional pasture systems. *Scientific Reports 13, 18658.*

Ylagan, S., **Brye, K**., Ashworth, A., Owens, P., Smith, H., Poncet, A., Sauer, T., Thomas, A., **Philipp, D. (**2023).Relationships Among Apparent Electrical Conductivity and Plant and Terrain Data in an Agroforestry System in the Ozark Highlands. Submitted. *Agrosyst Geosci Environ*. 6:e20414.

Grote, A., Nieman, C., **Coffey, K., Philipp, D., Kegley, E**. (2023). Using supplemental condensed tannin to mitigate tall fescue toxicosis in non-pregnant, non-lactating ewes consuming tall fescue silage. *Anim Feed Sci Technol* 295, 115516

*Abstracts:*

**Woody-Pumford RC, Bertucci MB, Richardson MD, Philipp D, Wright Smith H**. (2023). Assessing Injury and Mortality of Native Grass and Forb Species Treated with Common Roadside Herbicides. Presented at the American Society for Horticultural Science Meeting. August 4. Orlando, Florida.

Ethan Collins, **Mary C. Savin, Dirk Philipp, Ken Coffey**, Amanda Ashworth, **Trent Roberts**. (2023). No reduction of inorganic N losses observed in soil receiving synthetic or ruminant urine with increasing concentrations of hippuric acid. ASA-CSSA-SSSA Annual Meeting, St. Louis.

Nieman, C. M. Janorschke, **D. Philipp, M. Savin**. (2023). Establishing Cool-Season Forages in Thinned Hardwood Forests: Planting, Production, and Nutritive Value. Society of American Foresters Annual Meeting, Sacramento, CA.

*Outreach publications:*

Smith, R.S., **D. Philipp**, J. Fike, E. Johnson. 2023. Perennial Grassland Buffer Strip Practice Guide. grasslandpartnership.org (Report N. 2023-6)

Keyser, P.D., H. Naumann, S.R, Smith, M. Castillo, J. de Koff, and **D. Philipp**. Native grass forage practice guidelines. grasslandpartnership.org (Report N. 2023-2)

Fike, J., M. Castillo, H. Naumann, **D. Philipp**, L.S. da Silva. Climate smart practices – silvopasture practice introduction and implementation guide sheet. grasslandpartnership.org (Report N. 2023-5)

Popular press articles:

**Philipp, D.** and **J. Lovett.** Silvopasture can be established in pine tree alleyways.

The Farmer (Jan 22, 2023)

**Philipp, D.** and **J. Lovett.** Species diversity is key to enhancing soil carbon in grasslands.

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**Lovett, J. Quadros, D. Philipp, D., and Gunsaulis, J**. Sheep Field Day set for Oct 28, 2023). Multiple news outlets

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Arkansas Beef and Forage Corner:

**Philipp, D.** (2023). Native grass field borders will enhance sustainability.

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1. **Scientific and Outreach Presentations**

**Philipp, D**., Webinar – Beginning farmers and ranchers, "Pasture Management for Livestock" University of Arkansas - Pine Bluff, Online. (March 15th, 2023).

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* Morris, M. et al. (Philipp Co-PI): Soil for Water.
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* Richardson et al. (Philipp Co-PI): Developing a sustainable approach to roadside vegetation management in the State of Arkansas
  + Arkansas Department of Transportation; $350,000
* 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.

1. **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
* Rachel Pomford, MS Student (Univ. of Arkansas, Department of Horticulture); committee member, finished spring of 2024

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* Rachel Pomford, MS Student (Univ. of Arkansas, Department of Horticulture); committee member, finished spring of 2024

**Maryland State Report (University of Maryland)**

**NCCC-31 Report for 2023-24**

Ecophysiological Aspects of Forage Management

1. Impact Nugget

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. Our studies within forage crops and the surrounding farm landscape are designed to better understand their role in these ecosystems and their potential for conservation biological control.

2. New Facilities and Equipment

None

3. Unique Project Related Findings

We discovered that predatory and parasitic insect species are more abundant in a leafhopper-susceptible alfalfa cultivar than in a leafhopper-resistant cultivar. Parasitic hymenopterans (wasps) were especially abundant in samples, with more from the susceptible plots and from the resistant plots. This finding may explain aphid outbreaks reported on leafhopper-resistant alfalfa fields.

Agricultural drainage ditches sampled on Maryland’s Eastern Shore contain an abundant and ecologically diverse population of ground beetles as well as other types of natural enemies. Over 50 families of predatory and parasitic insects have been discovered in ditches, with many of these detected in the adjacent crops. We are studying their movement into adjacent crop fields to provide conservation biological control of insect pests.

4. Accomplishment Summaries

**Salerno, R., and W. Lamp**. Soil arthropod diversity and ecosystem services in response to ecological intensification of agricultural cropping systems. Soil biodiversity contributes substantially to soil health and crop productivity. Arthropods (insects, mites, springtails, etc.) provide ecosystem services including decomposition, biological control, and bioturbation. Outcomes from agricultural intensification have created challenges, leading to detrimental impacts on soil quality and soil arthropods. There is a need to develop sustainable and resilient agricultural systems which ensure food security and healthy environments for future generations. One promising approach involves ecological intensification, focusing on practices that support agroecosystems, bolstering biodiversity, ecosystem services, and production simultaneously. Despite these efforts, there remains knowledge gaps regarding the impact of ecological intensification on soil arthropod communities and abiotic soil properties.

During the past year, we investigated the response of soil arthropod communities and abiotic soil properties in forage cropping systems (perennial grass pastures and annual corn silage) and within adjacent non-crop habitats (mowed grass margins and woodlots) to better understand their contribution to biodiversity and ecosystems services on the farm. To do so, we sampled soil arthropods using subterranean pitfall traps and soil cores, and quantified soil quality and ecosystem service provisioning using the Soil Biological Quality – Arthropod Index and bait lamina testing, respectively. We have yet to analyze the subterranean trap data and several of the soil abiotic properties however, the results to date are as follows. For bait lamina testing, ANOVA revealed a significant effect of the treatment on the average feeding activity, F(3, 368) = 82.6, p < 2e-16. The effect size, measured by eta-squared (η²), was 0.402 signifying that 40.2% of the variance in feeding activity can be attributed to the differences between treatment groups. Most feeding activity was observed in the first 3cm of soil with the highest level of feeding activity for all plots at the 5mm depth. In terms of soil properties, soil bulk density was higher in corn plots than in all others F(3, 569) = 142.2, p < 2e-16. Soil moisture was highest in grass margin and woodlot plots and pH varied between treatments but was significantly lower in corn plots. Mesofauna abundance was highest in pastures and lowest in corn plots. Soil biological quality was higher in treatments with higher levels of feeding activity F(3, 63) = 14.15, p < 3.72e-7.3. Both semi-natural habitats possessed the highest soil biological quality index values, followed by pastures and grass margins respectively.

A graph showing the growth of plants

Description automatically generated with medium confidenceFig. 1. Mean (±S.E.) bait-lamina hole clearance (n=96) and selected soil abiotic properties (n=576) in four study treatments at the CMREC Clarksville Farm

**Brucchieri, A., and W. Lamp**. Characteristics of farm ponds that promote dragonfly reproduction for conservation biological control. While environmentally valuable, ponds on agricultural land are not usually installed or kept to support biodiversity but rather to provide social and economic benefits such as irrigation, stormwater management, and recreation. These ponds may offer additional services such as providing habitat for biological control agents, bridging the environmental and economic services. This study focuses on the order Odonata (dragonflies and damselflies). These insects are predatory as aquatic nymphs and terrestrial adults. After emergence, the adults will forage and in an agricultural setting this results in dragonflies acting as biological control agents. Factors including landscape conditions, water quality and function can influence a dragonfly’s reproductive success in farm ponds. To determine the influence of these factors we have sampled 15 ponds located on agricultural land in Maryland. Water quality sampling (including pH, conductivity and dissolved oxygen) and vegetation surveys were done once a month at each pond from June- August 2023. Macroinvertebrate samples were also done once a month to look at overall community structure and determine dragonfly species composition. Dragonfly nymphs have been sorted (Figure 1) and identified and vegetation surveys have been analyzed. The results are still being compiled and more characteristics are being assessed with the results of the 2024 field season including turbidity through analysis of total suspended solids and surveys are being sent to practitioners to determine management practices as well as the use of and the history of their ponds.

A graph of different colored bars

Description automatically generated

Fig. 2. Total number of dragonfly species found in each pond over the course of the Summer 2023 field season. These values demonstrate the variance of diversity across farm ponds in Southern Maryland.

**Stewart, J., and W. Lamp**. Potato leafhopper resistant alfalfa plots have fewer natural enemies than non-resistant alfalfa. The potato leafhopper (PLH) was a key pest of alfalfa before the deployment of a resistant cultivar. Though this cultivar suffers less injury from PLH, some research has indicated it may be more affected by other pests like aphids and the alfalfa weevil. Studying natural enemies in PLH resistant and susceptible cultivars may reveal why some pests are more abundant in the susceptible cultivar. At one of the University of Maryland’s research facilities, we created eight plots of alfalfa: four resistant (Pioneer 55H96) and four susceptible (Pioneer 55V50) to the PLH. Throughout the growing season, we sampled insects with sticky traps, sweep nets, and a D-vac. Additionally, we evaluated alfalfa health and growth through stem samples and weight-at-harvest.

We compared the diversity and abundance of natural enemies and key pests in the eight plots using T-tests, the Shannon Diversity Index, and other statistical methods. Susceptible plots averaged 43% fewer aphids between April 11th and July 24th compared to resistant plots. Sweep samples are not fully processed, so we cannot directly compare aphids to natural enemies. Despite the greater abundance of aphids in susceptible plots, there were generally fewer braconid wasps in them. Most of the braconids observed were aphid mummy wasps (Aphidinae). Coccinellids, another noted enemy of aphids, were not significantly more abundant in either susceptible or resistant plots. PLH resistant plots of alfalfa tended to have more aphids and fewer braconid wasps than PLH susceptible plots. This is curious because the main subfamily present was the aphid mummy wasp. Further, other natural enemies of aphids were more equally abundant across the two plots. The resistant cultivar may have fewer natural enemies due to reduced prey availability. Possibly, the trichomes the resistant cultivar uses to deter PLH also interfere with the ability of braconid wasps to detect their host.

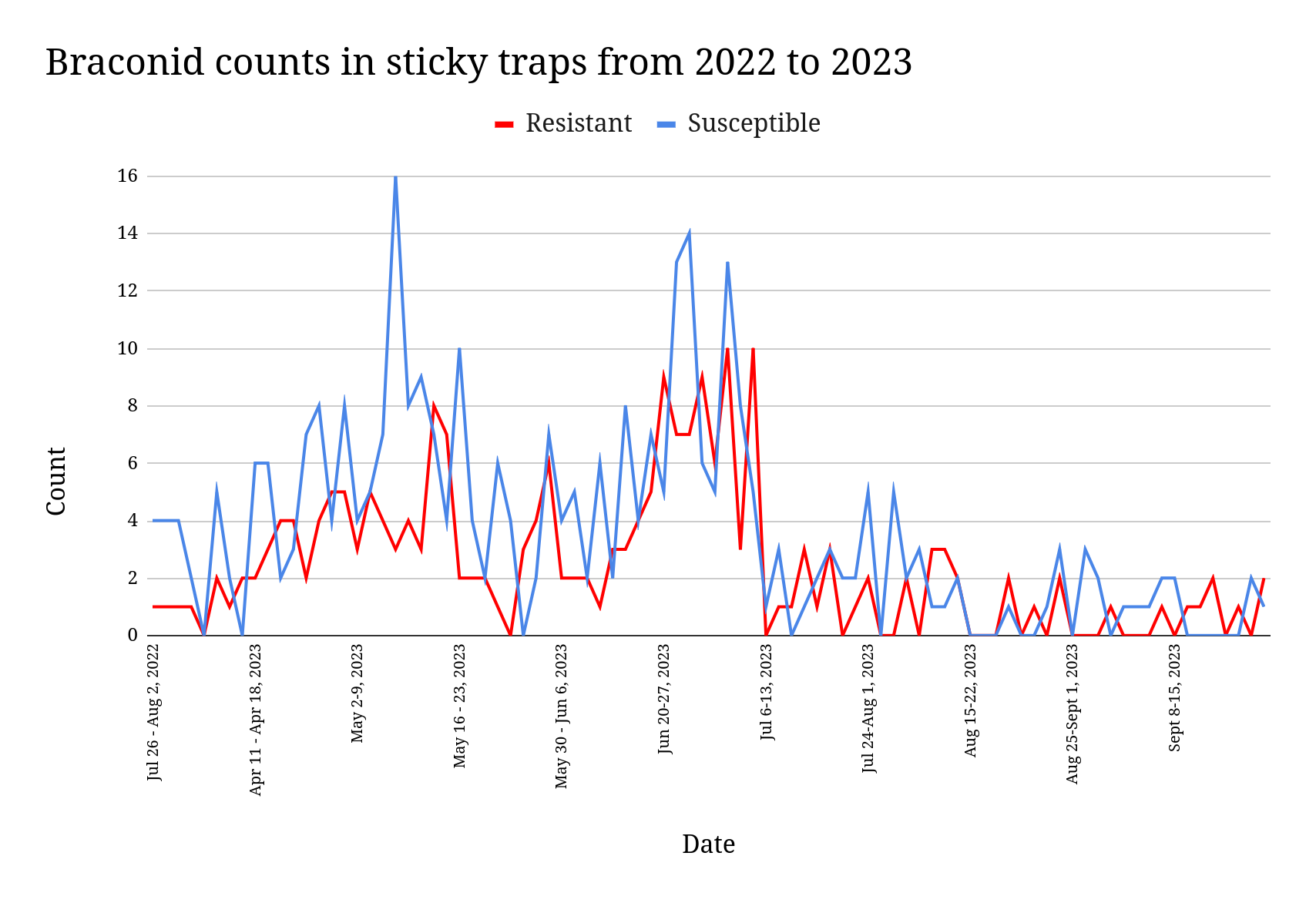


Fig. 3. Braconid wasp parasitoid counts on sticky traps, 2022-2023.

**Craig, H., A. Tiwari, R. Kohn, E. Rico, and W. Lamp**. Black soldier fly larvae (*Hermetia illucens*) as a climate mitigating protein supplement for dairy cattle. Insect protein has been used for food and feed globally throughout history (1), however its potential as a feed supplement in the livestock industry is only a recent idea within the last decade. Black soldier fly larvae (*Hermetia illucens*) (BSFL) protein has recently become more mainstream in food and feed science due to the relatively low need for land use, resources, and their low greenhouse gas emissions (2). Not only are BSFL emissions low, but as a feed they can actively reduce methane enteric emissions in vitro by 18.4% (3), however, more preliminary information is needed before implementing BSFL in a dairy cow’s diet. Our objectives were to (1) analyze the optimum inclusion ratio of BSFL in a cow’s diet to maximize methane mitigation while minimizing nutritional alterations, (2) examine the palatability and acceptability in dairy cows of feed with a 2% total inclusion of BSFL (25% substitution of the soybean meal), and (3) determine the degradation rate of BSFL in the rumen compared to soybean meal to assess nutrient release rate when substituting one for the other. For objective 1 we used in vitro fermentation to test three different inclusion ratios (10%, 25%, and 50% substitution of the soybean meal portion of the diet with BSFL) using two different BSFL meals (full fat and defatted). The data so far shows no changes in volatile fatty acid, methane, or CO2 production, however there is a difference in hydrogen production. For objective 2, we recruited 4 dairy cows and assigned two of the four cows to either a diet with BSFL or a normal diet without BSFL using a 2x2 latin square crossover design with two week treatment phases. The data from this experiment suggests the cows were unphased by the inclusion of BSFL into their diet. Finally, for objective 3, we recruited two fistulated cows to inoculate their rumen with packets of either BSFL or soybean meal over a period of 48 hours, packets were removed and processed to build a degradation curve over time. In summary, BSFL remains a viable protein substitute for soybean meal in dairy cows.

A graph with colorful lines and numbers

Description automatically generated

Fig. 4. In vitro methane production over 48 hours. None of the treatments were significantly different from each other except for the 24 hour time point of the 10% substitution of soybean meal with defatted BSFL.

A graph with different colored squares

Description automatically generated

Fig. 5. In vivo dry matter intake of BSFL and soybean meal in four cows (numbered 550, 560, 577, and 579). There was no difference in dry matter intake across the two treatments.

A graph with lines and dots

Description automatically generated

Fig. 6. In situ degradation rate of soybean meal and BSFL of 48 hours. Although soybean meal on average degrades more slowly than BSFL, there is no statistical difference between the two degradation rates.

[1] Costa-Neto et al. 2016. Insects as sustainable food ingredients (pp. 29-60). Academic Press.

[2] Van Huis et al. 2013. Food and agriculture organization of the United Nations.

[3] Ahmed et al. 2021. Animals, 11(9).

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*

None

*Extension publications*

Craig, H. Mcs., K. McIntyre, and W. Lamp. 2023. EntoQuest: A nod to the past and an opportunity for the future. American Entomologist 69: 30–33.

Craig, H., A. Righter, and W. Lamp. 2023. Assessment of ecosystems services provided by arthropods on farms: Preliminary use of sticky traps to sample flying insects. Roots in Research Newsletter 2022: 7-9.

Craig, H. 2024. Creative displays – Starting the conversation about insect ecosystem services. Maryland Grows Blog.

Salerno, R., and M. Ma. 2023. Supporting nature’s allies: Ground beetles and the role of

drainage ditches in agricultural pest control. UMD Entomology News.

Shokoohi, A., R. Salerno, and L. Kerner. 2023. Buzzkill: The chronic impact of neonicotinoids. UMD Entomology News.

7. Scientific and Outreach Presentations

Brucchieri, A. and Lamp, W. 2023. Characteristics of farm ponds that promote dragonfly reproduction for conservation biological control. EntoQuest, Entomological Society of America Meeting, DE

Brucchieri, A. and Lamp, W. 2023. Characteristics of farm ponds that promote dragonfly reproduction for biological control. Entomological Society of America Annual Meeting, National Harbor, MD.

Craig, H. and W. Lamp. 2023. Educating and empowering University of Maryland students on the importance of insect biodiversity in sustainability. Entomological Society of America Annual Meeting. National Harbor, MD.

Lin, E., S. Hu, H. Craig, and W. Lamp. 2023. Incorporating DNA barcoding in undergraduate courses to provide an enriched student experience with modern science. Innovations in Teaching and Learning Conference, University of Maryland, College Park, MD.

Salerno, R., and W. Lamp. 2024. The RCAP Graduate Student Forum: Past, present, and future. Resilience CAP All Hands Meeting, Fargo, ND.

Salerno, R., H. Denyer, and W. Lamp. 2024. Assessment of soil properties under different land use type on a cattle farm in central Maryland. NCCC31 Meeting, Fargo, ND.

Salerno, R., and W. Lamp. 2024. Beneath our feet: Cultivating resilience with agriculture’s hidden heroes. Minute Thesis Competition, University of Maryland, College Park, MD.

Salerno, R., H. Denyer, and W. Lamp. 2024. Bait lamina strips reveal lower rates of decomposition in corn-soy rotation fields compared to perennial forage pastures. Resilience CAP Meeting, Fargo, ND.

Salerno, R., and W. Lamp. 2023. Subterranean arthropod sampling of agroecosystem semi-natural habitats: A comparison of techniques. Entomological Society of America National Meeting, National Harbor, MD.

Salerno, R., and A. Brucchieri. 2023. The Resilience CAP grant Graduate Forum: Our beginning and what’s next. Resilience CAP Meeting, Madison, WI.

Salerno, R., and W. Lamp. 2023. Evaluating ground beetle (Coleoptera: Carabidae) movement between agricultural drainage ditches and arable fields: A case history for conservation biological control. Resilience CAP Meeting, Madison, WI.

Shechtman, F.J., H. Craig, A. Righter, and W. Lamp. 2023. Use of sticky traps to compare patterns of flying insect biodiversity on farms: taxa diversity and ecological roles. Entomological Society of America Annual Meeting. National Harbor, MD.

Shokoohi, A. and W. Lamp. 2023. Developing management practices for agricultural drainage ditches to enhance biological control by ground beetles. Eastern Branch, Entomological Society of America Meeting, Providence, RI.

Stewart, J., Craig, H., Lamp, B. 2023. Potato leafhopper resistant alfalfa plots have fewer natural enemies than non-resistant plots. Entomological Society of America Meeting, National Harbor, MD.

Windsor, S., Shokoohi, A., and W. Lamp. 2023. Analyzing spatial and temporal distribution of hymenopteran parasitoids within agricultural drainage ditches and adjacent cropland. Poster, Entomological Society of America Meeting, National Harbor, MD.

8. Collaborative Grants

Craig, Helen, and William Lamp. University of Maryland Sustainability Fund, 2023-2024, “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

Shokoohi, Alireza, MS, May-2024, “Enhancing biological control by ground beetles (Coleoptera: Carabidae) through agricultural drainage ditch management practices.”

Hartman, Margaret, MS, May-2024, “Odonata species composition in agroecosystems: Preliminary surveys with an emphasis on potential for biological control on farms”

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, MS, May-2026, “Evaluating insect feed as a climate mitigating protein supplement for dairy cattle”

**University of Kentucky**

**NCCC-31 Report, 2023-2024**

Ecophysiological Aspects of Forage Management

1. Impact Nugget

The forage 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 change and mitigation potential. 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. The documents are out for bid at present. The project is currently running behind schedule, with opening in 2026 currently looking optimistic. The project has been delayed by other UK construction projects and by issues with the bid process.

In western Kentucky, new permanent buildings are being erected to house the UK faculty and staff displaced by the tornado of December 2021. Barns are being built – some are functional - and the walls of the main building are currently going up. Completion of the entire rebuild is still projected for end of 2025.

3. Unique Project Related Findings

Sustainable growth in livestock production requires reductions in trace gas emissions on grazing lands. Urine excreta patches are hot spots for accelerated emissions of carbon and nitrogen. Ruminant dietary supplementation with the isoflavone biochanin A (BCA) has been shown to improve cattle weight gain. To determine if BCA supplementation affects urine N excretion and soil trace gas emissions, soil in microcosms was amended with urine from lambs fed 0, 0.45, or 0.90 g BCA day−1. Soil gas emissions

were measured over 60 days and analyzed with a linear mixed-effects model with repeated measures. On 2 days during the incubation, BCA addition across doses significantly reduced nitrous oxide emissions by 73% and methane by 98% compared to urine from non-dosed lambs. Cumulative ammonia volatilization was significantly reduced by 33% but cumulative nitrous oxide and methane emissions were not. Alterations in trace gas emissions occurred despite no change in urine N content with BCA feed supplementation. A separate laboratory incubation using urine from a non-supplemented lamb that was exogenously spiked with varying BCA concentrations supported these results: BCA significantly altered ammonia and methane emission dynamics and reduced cumulative nitrous oxide emissions by up to 41%. BCA did not change soil microbial community structure, suggesting alterations to other processes,

such as soil enzyme activity, were affecting soil trace gas emissions. Overall, lamb BCA supplementation did not affect urine N but reduced ammonia volatilization, which may contribute to greater sustainability in livestock production systems. ***– Jacobs, A.A. et al. 2024. Journal of Environmental Quality.***

4. Accomplishment Summaries

During 2023-2024, 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. Outreach activities included various trainings throughout the state and participation in numerous national and regional meetings. Two students graduated (both MS), and several other new students were started. Forage-related research in the Pyrenees of France continued, based on funding from NSF. A second student intern was advised as part of the AFRI-SAS-CAP grant effort linked to NCCC-31.

5. Impact Statements

***"Tall fescue and endophyte genetics influence vertical transmission and seed characteristics under climate change scenarios" - McGrail et al. 2024. Phytobiomes.***

*Issue:* Cool season grasses, including tall fescue, are dominant plants within managed grassland systems. A symbiotic relationship between tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh) and fungal endophyte (*Epichloë coenophiala*) can affect grassland response to perturbations, including changing rainfall patterns and increasing temperatures associated with climate change. Because *E. coenophiala* reproduces asexually, there is concern that climate change may negatively impact vertical transmission, resulting in subsequent fescue stands with lower infection frequencies and reduced grassland resiliency.

*Action:* This three-year field study evaluated the impact of increased temperature, altered precipitation, and their combination on vertical transmission, seed number, and seed weight in tall fescue clones containing common toxic (CTE) or novel non-mammalian toxic (NTE) *E. coenophiala*.

*Impact:* NTE clones exhibited greater transmission than CTE clones. Temperature did not affect transmission, but altered precipitation reduced transmission in CTE clones. On average, NTE clones responded to increased temperatures by reducing seed number, while CTE clones responded oppositely. NTE clones produced seeds of similar mass across all growing years suggesting greater stability under varying environmental conditions. Our work illustrates both plant and endophyte genetics influence vertical transmission and that climate change is unlikely to significantly impact endophyte transmission in the southeastern transition zone of the United States.

***"Widening global variability in grassland biomass since the 1980s" - MacDougall et al. 2024. Nature Ecology & Evolution.***

*Issue:* Global change is associated with variable shifts in the annual production of aboveground plant biomass, suggesting localized sensitivities with unclear causal origins.

*Action:* Combining remotely sensed normalized difference vegetation index data since the 1980s with contemporary field data from 84 grasslands on 6 continents, we show a widening divergence in site-level biomass ranging from +51% to −34% globally.

*Impact:* Biomass generally increased in warmer, wetter and species-rich sites with longer growing seasons and declined in species-poor arid areas. Phenological changes were widespread, revealing substantive transitions in grassland seasonal cycling. Grazing, nitrogen deposition and plant invasion were prevalent in some regions but did not predict overall trends. Grasslands are undergoing sizable changes in production, with implications for food security, biodiversity and carbon storage especially in arid regions where declines are accelerating.

6. Published Written Works

***Refereed publications***

Jacobs, A.A., M.D. Flythe, D.G. Ely, L. Munoz, J.B. May, J.A. Nelson, V. Stanton, R.K. McGrail, K. Pham, and ***R.L. McCulley***. **2024**. Biochanin A feed supplementation alters dynamics of trace gas emissions from lamb urine-amended soil. Journal of Environmental Quality.

MacDougall, A., E. Esch, Q.Q. Chen, O. Carroll, C. Bonner, T. Ohlert, M. Siewert, J. Sulik, A. Schweiger, E.T. Borer, D. Naidu, S. Bagchi, Y. Hautier, P. Wilfahrt, K. Larson, J. Olofsson, E. Cleland, R. Muthukrishnan, L. O’Halloran, J. Alberti, T.M. Anderson, C.A. Arnillas, J.D. Bakker, I.C. Barrio, L. Biederman, E.H. Boughton, L.A. Brudvig, M. Bruschetti, Y. Buckley, M.N. Bugalho, M.W. Cadotte, M.C. Caldeira, J.A. Catford, C. D’Antonio, K. Davies, P. Daleo, C.R. Dickman, I. Donohue, M.E. DuPre, K. Elgersma, N. Eisenhauer, A. Eskelinen, C. Estrada, P.A. Fay, Y. Feng, D.S. Gruner, N. Hagenah, S. Haider, S. Harpole, E. Hersch-Green, A. Jentsch, K. Kirkman, J.M.H. Knops, L. Laanisto, L.S. Lannes, R. Laungani, A. Lkhagva, P. Macek, J.P. Martina, ***R.L. McCulley***, B. Melbourne, R. Mitchell, J.L. Moore, J.W. Morgan, T.O. Muraina, Y. Niu, M. Partel, P.L. Peri, S.A. Power, J.N. Price, S.M. Prober, Z. Ren, A.C. Risch, N.G. Smith, G. Sonnier, R.J. Standish, C.J. Stevens, M. Tedder, P. Tognetti, G.F. Veen, R. Virtanen, G.M. Wardle, E. Waring, A.A. Wolf, L. Yahdijian, and E.W. Seabloom. **2024**. Widening global variability in grassland biomass since the 1980s. Nature Ecology & Evolution.

McGrail, R.K., A.E. Carlisle, J.A. Nelson, R.D. Dinkins, and ***R.L. McCulley***. **2024**. Tall fescue and endophyte genetics influence vertical transmission and seed characteristics under climate change scenarios. Phytobiomes.

Jacobs, A.A., R.S. Evans, J.K. Allison, W.L. Kingery, ***R.L. McCulley***, and K.R. Brye. **2024**. Tillage and cover crop systems alter soil particle size distribution in raised-bed-and-furrow row-crop agroecosystems. Soil Systems 8(1): 6. doi.org/10.3390/soilsystems8010006

Siebert, J., M. Sünnemann, Y. Hautier, A.C. Risch, J.D. Bakker, L. Biederman, D.M. Blumenthal, E.T. Borer, M.N. Bugalho, A.A.D. Broadbent, M.C. Caldeira, K.F. Davies, A. Eskelinen, N. Hagenah, J.M.H. Knops, A.S. MacDougall, ***R.L. McCulley***, J.L. Moore, S.A. Power, J.N. Price, E.W. Seabloom, R. Standish, C.J. Stevens, S. Zimmermann, and N. Eisenhauer. **2023**. Drivers of soil biological activity across global grasslands. Communications Biology 6, Article number: 1220.

Spohn, M., S. Bagchi, L.A. Biederman, E.T. Borer, K.A. Brathen, M.N. Bugalho, M.C. Caldeira, J.A. Catford, S.L. Collins, N. Eisenhauer, N. Hagenah, S. Haider, Y. Hautier, J.M.H. Knops, S.E. Koerner, L. Laanisto, Y. Lekberg, J.P. Martina, H. Martinson, ***R.L. McCulley***, P.L. Peri, P. Macek, S.A. Power, A.C. Risch, C. Roscher, E.W. Seabloom, C. Stevens, G.F. Veen, R. Virtanen, and L. Yahdjian. **2023**. The positive effect of plant diversity on soil carbon depends on climate. Nature Communications 14, Article number: 6624.

***Proceedings publications***

None to report.

***Extension Publications***

Lea, K. S. Smith, and R. Smith. **2023**. Tall Fescue Novel Endophyte Varieties and Establishment for Livestock and Horse Farms. AGR-275.

Burdine, K., K. Mercier, and R. Smith. **2024**. The Great Debate of Annual vs. Perennial Forages. ID-277.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2023**. 2023 Timothy and Kentucky Bluegrass Report. PR-840.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2023**. Red and White Clover and Annual Lespedeza Report. PR-836.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2023**. 2023 Long-Term Summary of Kentucky Forage Variety Trials. PR-846.

Bruening, B., J. Henning, G. Olson, R. Smith, and C. Teutsch. **2023**. 2023 Annual Grass Report: Warm Season and Cool Season (Cereals). PR-845.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2023**. 2023 Cool-Season Grass Grazing Tolerance Report. PR-843.

Henning, J., L. Lawrence, G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2023**. 2023 Cool-Season Grass Horse Grazing Tolerance Report. PR-844.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2023**. Alfalfa, Red Clover and White Clover Grazing Tolerance Report. PR-842.

Olson, G. T. Phillips, R. Smith, and C. Teutsch. **2023**. 2023 Orchardgrass Report. PR-838.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2023**. 2023 Annual and Perennial Ryegrass and Festulolium Report. PR-841.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2023**. 2023 Alfalfa Report. PR-837.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2032**. 2023 Tall Fescue, Bromegrass, and Meadow Fescue Report. PR-839.

7. Scientific and Outreach Presentations

1. Wolfe, A.J., A.A. Jacobs, J.A. Nelson, A.E. Carlisle, R.K. McGrail, and R.L. McCulley. **2023**. Effect of grass-endophyte symbiotic diversity on pasture soil health in Kentucky. ASA-CSSA-SSSA Annual Meeting, St. Louis, MO.
2. McGrail, R.K., R.C. Pearce, S.T. Lucas, L. Moe, and R.L. McCulley. **2023**. Nutrient dynamic considerations for fiber dew retting. ASA-CSSA-SSSA Annual Meeting, St. Louis, MO.
3. McGrail, R.K., R.C. Pearce, S.T. Lucas, L. Moe, and R.L. McCulley. **2023**. Inclusion of industrial hemp in Kentucky's cropping rotation: effects on agroecosystem function. ASA-CSSA-SSSA Annual Meeting, St. Louis, MO.

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

**Echo Gotsick**, MS in Integrated Plant & Soil Sciences, graduated **2023**, "Comparison of botanical composition methods and change over time in Kentucky pastures." University of Kentucky Libraries. https://doi.org/10.13023/etd.2023.104

**William Fleming**, MS in Integrated Plant & Soil Sciences, graduated **2024**, “Surveys, field studies, and laboratory incubation experiments to improve alfalfa production in the Mid-South.” University of Kentucky Libraries. https://doi.org/10.13023/etd.2024.288

**Reilly Kaplan-Fardy**, MS in Integrated Plant & Soil Sciences, expected graduation **2024**, title - TBD.

**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.

**North Dakota Report 2023-2024**

**North Dakota State University**

1. **Impact Nugget:**

Forages research in North Dakota has its main focus in alfalfa production management and cover crops for grazing. Integration of forages research into annual cropping systems increases the delivery of ecosystem services, enhancing resilience and stability.

**2. New Facilities and Equipment:**

None

1. **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 2023, the corn-alfalfa intercropping experiments established in 2020 and 2021were harvested in 2023 showing forage yield was the same in all treatments and we could not distinguish plots established in intercropping with corn and those established alone. Alfalfa can be established with corn successfully, establishment at a 152-cm row spacing of corn is more consistent over the years, but at this row spacing a significant yield loss in corn is expected. 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-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 location in 2023.

***1)*** ***Alfalfa-sunflower intercropping***. Treatments were alfalfa alone, sunflower alone at 76- and 152-cm row spacing, and sunflower intercropped with alfalfa at 76- and 152-cm row spacing. Sunflower achene yield in both years was the same for all treatments and alfalfa establishment and yield was the same 2 years after establishment.

***2)*** ***Forage sorghum-corn intercropping*** with two cut systems. Corn yield was lower only when it was intercropped with alfalfa and gaps for additional light were added. Forage sorghum biomass yield was the same with or without intercropped alfalfa. Forage sorghum in 1-cut system had significant higher yield than when two cuts were done. Alfalfa plant density and seasonal forage yield in the following season was lower only in the 1-cut system FS. In all other treatments, alfalfa establishment was good and ranged between 40 and 45 plants/m2.

***3)*** ***Alfalfa and sainfoin*** were intercropped with sunflower in Hickson and Prosper, ND, with seven treatments and four replicates. Treatments did not have significant impact on sunflower achene yield (1800-3400 kg/ha) at both 40 and 80 N kg/ha fertilizer rates. Alfalfa maintained expected forage yield for the first cut, while sainfoin lagged slightly in intercropping but excelled as a mono crop. Intercropping enhanced biodiversity in both locations.

***4) Alfalfa-sainfoin intercropping:*** The viability and advantage of incorporating alfalfa into a cropping system was examined on alfalfa establishment in an intercropping system with FS. Sainfoin and alfalfa were intercropped with FS in Hickson and Prosper, ND, with seven treatments and four replicates. Intercropping treatments did not have significant impact on FS 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.

***Perennial cool-season grasses:*** The objective of this study was to evaluate new perennial cool-season grasses varieties for improved forage yield, nutritive value, and winter hardiness. Grasses were established in Prosper and Hickson, ND in 2020. Several varieties of orchardgrass (OG) (4), meadow fescue (MF) (3), tall fescue (TF) (6), perennial ryegrass (PRG) (3), meadow brome (MB) (2), smooth brome (SB) (2), crested wheatgrass (CWG), intermediate wheatgrass (IWG), creeping wheatgrass (hybrid CWG x IWG), and a dryland mix, for a total of 24 treatments were tested. In 2023, the yields were really low due to drought. Intermediate wheatgrass, smooth and meadow brome, and creeping wheatgrass had the highest forage yield (~ 7 Mg/ha/year) and still had a full stand in 2023 indicating long persistence. PRG varieties did not survive the winter.

***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 2023, 15 FS, SS, and FS blends were tested, including photoperiod sensitive (PS) sorghums, FS types, and double purpose (DP). In 2023, forage yield ranged between 5.6 and 14.7 Mg/ha. The highest yields were obtained with PS hybrids. Forage nutritive value was adequate to feed a 2000 lbs beef cow; average crude protein was 12.1% and total digestible nutrients average was 67.8%. This is part of a new project aimed to select FS lines adapted to northern climates.

**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.

1. ***Forage sorghum and sudangrass impact:***

Forage sorghum is drought tolerant and feed quality is similar to corn silage. It can easily yield up to 10 tons DM/acre in ND at $30-50/ton for a biomass feedstock gross income from $300 to $500 per acre. 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**.

1. ***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.

1. ***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 at $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 cost of fertilizer would be 3,965,380 acres x 10% x $60/acre= **$23,792,280/ yr.**

1. ***Bioenergy crops-impact:***

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

1. ***Cover crops increased adoption impact:***

Cover crops reduce erosion and retain nutrients that otherwise will be lost to run-off or leaching and in the long-term increase soil organic matter and soil health. The research of interseeding cover crops into standing corn and soybean or after wheat has indicated cover crops retain 30-50 lbs of N in their biomass. With a very conservative N credit to cover crops of only 10 lbs N/acre, the economic value of reducing the fertilization in 10% of corn acres in ND, 3,965,380 acres x 10 lbs N/acre saving x $ 0.8 lb N, is equal to **$3,172,304/yr.** Cover crops forage value can add $20/acre revenue by grazing. If only 1% of the wheat acreage (6,506,733 acres) was planted to cover crops for grazing after harvest, the economic impact would be **$1,301,346/yr.**

1. ***Reduction in greenhouse gases emissions and carbon intensity impact:***

In addition, both cover crops and perennial forages are part of the strategy to increase carbon sequestration in regenerative agriculture. Increasing the value of the land of producers that demonstrate their fields sequester carbon. Perennial crops, such as alfalfa and perennial forages are carbon sinks due to their deep root systems. Companies contracting carbon credits for regenerative practices are offering $5-10/acre for adopting perennial crops, no-tillage and/or cover crops. Our research is promoting the integration of perennial crops into annual cropping systems. If only 5 million acres of cropland in ND adopts regenerative practices and join a carbon credit program the impact in revenue to the states would be of **25 to $50 million**. There is no doubt that forages and cover crops will have a very important role in N2 fixation, C sequestration, and C markets in the near future.

**In summary,** the forages, bioenergy, and cover crops research in my project has an impact to the state’s economy of about **$268 million per year.**

**5. Published written work**

*Peer-reviewed publications*

1. 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. 2025. Applied Vegetation Science *(Under review)*
2. Spiess, J., C. Gasch, D. McGranahan, T. Hovick, M.T. Berti, and B. Geaumont, B. 2025. Soil nutrients and microbial community resistant to patch-burn grazing in southwestern North Dakota. Ecological monographs *(Under review)*
3. McGranahan, D.A., M.R. Wanchuck, K. Sedivec, M.T. Berti, K.C. Swanson, and T.J Hovick. 2024. Variability in weight gains of cows and their calves across grazing management and mother age class: Implications for maternal productivity. Rangeland Ecology & Management *(accepted)*
4. Spiess, J., D. McGranahan, M.T. Berti, C. Gasch, T. Hovick, B. Geaumont, B. 2024. Spatio-temporal patterns of rangeland forage nutritive value and grazer selection with patch-burning in the US northern Great Plains. J. Environmental Management 57:120731, https://doi.org/10.1016/j.jenvman.2024.120731
5. Wanchuk, M. D.A. McGranahan, K.K. Sedivec, M.T. Berti, K.C. Swanson, T.J. Hovick, R.F. Limb. 2024 Improving forage nutritive value and livestock performance with spatially-patchy prescribed fire in grazed rangeland. Agriculture, Ecosystems & Environment 368: 10190004, https://doi.org/10.1016/j.agee.2024.109004

*Scientific and Outreach Presentations*

1. Berti, M.T. 2024. What is the value of alfalfa in a diverse multicrop rotation? ND Soil and Water Conservation Society Annual Meeting. Dickinson, ND, 19 September, 2024 Invited speaker.
2. Omeye, F., Berti, M.T., Mosqueda, H., Lindell, H., Islam, Md.S., Morocho-Lema, M., and Igboke, O. 2024. Establishing alfalfa or sainfoin in an intercropping system with forage sorghum. Annual meeting NCCC31 Forage committee and R-CAP, Fargo ND, 12-15 August, 2024.
3. Islam, Md.S., Berti, M.T., Omeye, F., Mosqueda, H., Igboke, O., and Grijalba, M. 2024. Establishing alfalfa and sainfoin through intercropping with sunflower. Annual meeting NCCC31 Forage committee and R-CAP, Fargo ND, 12-15 August, 2024.
4. Mazala, M., Tabert, M., Islam, Md.S., Anderson, J.V., Horvath, D.P. and Berti, M.T. 2024. Transcriptomic analysis of alfalfa-sunflower intercropping. Annual meeting NCCC31 Forage committee and R-CAP, Fargo ND, 12-15 August, 2024
5. Igboke, O., Berti, M.T., Mosqueda H/, Lindell, H., Islam, Md.S., Morocho-Lema, M., and Omeye, F. 2024. Comprehensive life cycle assessment of forage cropping systems for sustainable agriculture. Annual meeting NCCC31 Forage committee and R-CAP, Fargo ND, 12-15 August, 2024.
6. Omeye, F., Berti, M.T., Mosqueda, H., Kurth, A., Lindell, H., and Islam, Md.S. 2024. Establishing alfalfa or sainfoin in an intercropping system with forage sorghum. Soil Water Conservation Society Annual Conference, Myrtle Beach, NC 21-24 July 2024.
7. Islam, Md. S,. and M.T. Berti. 2024. Establishing alfalfa and sainfoin thorough intercropping with sunflower Soil Water Conservation Society Annual Conference, Myrtle Beach, NC 21-24 July 2024.
8. Igboke, O., Bortolon, E.S.O., and Berti, M.T. 2024. Terrestrial acidification, ecotoxicity, eutrophication potential are reduced in production systems that include perennial forages. North American National Alfalfa Improvement Conference, Pasco, WA, 24-26 June 2024.
9. Islam, Md.S., and M.T. Berti. 2024. Intercropping alfalfa and sainfoin with sunflower boosts forage production, soil health, and biodiversity. North American Alfalfa Improvement Conference, Pasco, WA, 24-26 June 2024.
10. Berti, M.T., Buecking, H., and Bauder, S. 2024. Integrating alfalfa (Medicago sativa L.) into annual cropping systems to enhance soil microbiome diversity and nutrient cycling International Union of Soil Sciences, Florence, Italy 20-22 May.
11. Omeye, F. M.T. Berti, H. Mosqueda, A. Kurth, H. Lindell. And Md S. Islam. 2024. Increased Forage Yield and Nutritive Value of Forage Sorghum Grown in Intercropping with Alfalfa. American Forage Grassland Conference, Mobile AL January 8-10, 2024.
12. Berti, M.T., 2023. Seed mixes for full-season cover crops and those planted after harvest. SWCS annual conference, Protecting the Soil: A key to resilient cropping and grazing systems. 12-13 December, 2023, Fargo, ND. Invited speaker.
13. Berti, M.T., 2023. Can we count the nitrogen credits of cover crops for the following cash crop? 19th Annual Soil management Summit, 7-8 December, 2023, Alexandria, MN. Invited speaker.
14. Berti, M.T., and E.S. Bortolon. 2023. Perennial Forage Cropping Systems Have Lower Global Warming Potential and Environmental Impact Than Annual Forage Systems. [Abstract] ASA-CSSA-SSSA International Annual Conference, St, Louis, MO, 29 Oct-1 Nov, 2023.
15. Mosqueda H., M.T. Berti, S. Bibby, A. Kurth, and H. Lindell. 2023. Integrating Alfalfa into Corn or Forage Sorghum to Increase System Diversity and Perenniality. [Abstract] ASA-CSSA-SSSA International Annual Conference, St, Louis, MO, 29 Oct-1 Nov, 2023.
16. Kurth, A.K., M.T. Berti, H.M. Mosqueda, H. Lindell, S. Islam, and F. Omeye, 2023 Integrating Alfalfa and Winter Camelina into Wheat-Sunflower-Soybean Rotations. [Abstract] ASA-CSSA-SSSA International Annual Conference, St, Louis, MO, 29 Oct-1 Nov, 2023.
17. Mosqueda, H and M.T. Berti. 2023. Biodiversity of intercropped corn or sorghum with alfalfa in establishment year. Soil Water and Conservation Society, Des Moines, IA 6-9 August 2023.
18. Berti, M.T., M. Tabert, and J.V. Anderson. 2023. Alfalfa-sunflower intercropping is a profitable way to establish alfalfa. 34th Annual Conference Association for the Advancement of Industrial Crops, Corvallis, OR, 27-30 August 2023.

*Other publications (magazines, extension/online/bulletins)*

1. Berti M.T. 2023. Weed control in established alfalfa and terminating a stand. Forage Focus Magazine December 2023. Midwest Forage Association, St. Paul, MN p. 14.

**7*. Collaborative grants (new)***

* 1. USDA-NIFA-ASFAS, 9/2024-8/2027. Northern exposure: Adaptation of alfalfa for challenging winter climates. $924,032, PI. Award no. 2024-06270
  2. USDA-CERL 9/2023-8/2027. Effects of enhanced floral resources and nutrition on pollinators and insect pests across ecological, organismal, and molecular levels. $2,454,713 ($363,684 to my program). Co-PI. Award no. W913T2-23-2-0009

**8. Graduate students**

**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.

**Shazzadul Islam, MS,** Plant Sciences**.** Sunflower-alfalfa and sainfoin intercropping. Expected graduation date: May 2025. Advisor: Berti

**Franklin Omeye,** **MS,** Plant Sciences. Forage-sorghum alfalfa and sainfoin intercropping. Expected graduation date: December 2025. Advisor: Berti

**Anastasia Kurth, MS,** Plant Sciences**.** Introducing alfalfa and camelina in rotation with early maturing sunflower. Graduation date: May 2024. Advisor: Berti (Resilience-CAP)

**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: December. 2024. Advisor: Geddes

**Garret Levin, PhD,** Microbiology. *Sinorhizobium* in alfalfa. Expected graduation date: Expected graduation date: December 2024. Advisor: Geddes

**TENNESSEE**

**UNIVERSITY OF TENNESSEE (RENATA NAVE OAKES)**

**ACCOMPLISHMENTS**

**Short-term Outcomes:**

This year we prioritized the publication of Dr. Marcia Quinby’s PhD work, on corn production under the white clover living mulch systems.

We were able to publish two manuscripts, as well as an abstract proceedings at the International Grassland Congress held in Kentucky.

**Outputs:**

Results originated from the project titled “Diversifying corn production systems with white clover living mulch” which encouraged us to continue research in this area. We were able to submit a proposal to the NIFA-Organic Transitions Program, and received funding to initiate a project focusing on the use of perennial legumes as living mulched for organic corn production. The project is currently underway.

**Activities:**

N/A

**Milestones:**

N/A

**IMPACTS**

Perennial forage legumes, such as white clover, can be included as a living mulch in corn silage and grain production in the Southeast. White clover decreases the need to plant cover crops annually and also leads to a reduction in weed pressure. Under normal weather conditions, corn grain and silage produced similar yields, but adding white clover allowed for a greater overall production, likely due to the added N. White clover as a living mulch also showed positive applications in grazing systems, but further studies are warranted to help advance the use of living mulch in the Southern U.S.

**PUBLICATIONS**

Quinby, M\*., R.L.G. Nave, Sykes, V. R., Bates, G. E., C. Sams and O.G. Almeida. 2023. Corn (Zea mays L.) Production in Living Mulch Systems Using White Clover (Trifolium repens L.) under Different Nitrogen Fertilization Rates. Agronomy. doi.org/10.3390/agronomy13092377.

Almeida, O.G\*., C.G.S. Pedreira, J. Assis, B.C. Pedreira, F. Junior, and R.L.G. Nave. 2023. Defoliation management and nitrogen fertilizer rate affect canopy structural traits of grazed guineagrass (Megathyrsus maximus) cv. Zuri under rotational stocking. Crop and Pasture Sci. doi:10.1071/CP22388.

Quinby, M\*., R.L.G. Nave, Sykes, V. R., Bates, G. E., and M. Levi and N. Hill. 2023. Diversifying corn production systems with living mulches in the southeastern United States. doi.org/10.1002/agj2.21294.

**NCCC-31**

**Ecophysiological Aspects of Forage Management**

**Utah Report 2024**

1. Impact Nugget

As part of the Smart Foodscapes study, we demonstrated that the native plants blanketflower, leadplant, purple prairie clover, Utah sweetvetch, and white prairie clover accumulate condensed tannins, and that the native plants blanketflower, Maximillian sunflower, prairie aster, prairie coneflower, purple prairie clover, showy goldeneye, smooth blue aster, and Utah sweetvetch accumulate hydrolysable tannins. The plants that accumulate both types of tannins – blanketflower, purple prairie clover, and Utah sweetvetch – are of particular interest because it has been demonstrated that including both types of tannins in ruminant diets is an effective approach to reducing greenhouse gas emissions.

2. New Facilities and Equipment

3. Unique Project Related Findings

4. Accomplishment Summaries

In her report, Dr. MacAdam discussed the quantitative and qualitative analysis of condensed and hydrolysable tannins in perennial legumes and non-legume forbs.

5. Impact Statements

6. Published Written Works

*Refereed publications*

Beyaz, R. and J.W. MacAdam. 2023. X-radiation of *Lotus corniculatus* L. seeds improves germination and initial seedling growth. *International Journal of Radiation Biology* DOI: [10.1080/09553002.2023.2204961](https://doi.org/10.1080/09553002.2023.2204961)

Bleke, C.A., E.M. Gese, S.B. Roberts, J.J. Villalba. 2023. Seasonal shifts in pronghorn antelope (*Antilocapra americana*) diets under a new lens: Examining diet composition using a molecular technique. Plos one 18 (10), e0292725.

Chen, L., Y. Wang, X. Li, J. MacAdam, and Y. Zhang. 2023. Interaction between plants and epiphytic lactic acid bacteria to affect plant silage fermentation. *Frontiers in Microbiology* 14: 1745.

Greenland, M.S., B.L. Waldron, S.C. Isom, S.D. Fonnesbeck, M.D. Peel, K.A. Rood, K.J. Thornton, R.L. Miller, J.A. Hadfield, B. Henderson, and J.E. Creech. 2023. Dry matter intake and feed efficiency of heifers from 4 dairy breed types grazing organic grass and grass-birdsfoot trefoil mixed pastures. Journal of Dairy Science, 106: 3918-3931.

Klotz, J. L., J. W. MacAdam, and M. D. Flythe. 2023. Editorial: Natural Products in Animal Feed and Production Systems. Special Research Topic, Animal Nutrition Section, *Frontiers in Animal Science* 4:1204663.

Loveland, L.C., S.B. Orloff, M.A. Yost, M. Bohle, G.C. Galdi, T. Getts, D.H, Putnam, C.V. Ransom, D.A. Samac, R. Wilson, and J.E. Creech. 2023. Glyphosate‐resistant alfalfa can exhibit injury after glyphosate application in the Intermountain West. *Agronomy Journal*, 115: 1827-1841.

Roberts, C. D., M.A. Yost, J.G. Robins, C.V. Ransom & J.E. Creech. 2023. Oat companion seeding rate, herbicide, and irrigation effects on alfalfa stand establishment. *Agronomy Journal*, 115: 273-285.

Provenza, F.D., J.J. Villalba, and G.S. Kleppel. 2023. Livestock production and the functioning of agricultural ecosystems, Volume II. *Frontiers in Sustainable Food Systems* 6, 1117790.

Seeno, E., J. MacAdam, A. Melathopoulos, S. Filley, and S. Ates. 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*, 78: 462-479.

*Proceedings publication*

MacAdam, J.W., J.J. Villalba, S. Lagrange, E. Stewart, S. Hunt, J. Legako, R. Christensen, R.L. Pitcher, R.L., and A. Bolletta. 2023. Tannins in perennial legume and forb functional forages. Proc. XXV International Grassland Congress, 14-19 May 2023, Covington, Kentucky, USA.

Villalba, J.J., J.W. MacAdam, S. Van Vliet, and F.D. Provenza. 2023. Integrating plant secondary metabolites and foraging behavior to enhance animal health in ruminant production systems. Proc. XXV International Grassland Congress, 14-19 May 2023, Covington, Kentucky, USA.

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

PhD

Zubair Barkat

Andrea Loudenback

Iddy Muzzo

Master’s

Horacio Blanchard

Taylor Jackson

Sebastian Schreiber-Pan

Surbhi Verma,

**NCCC-31**

**Ecophysiological Aspects of Forage Management**

**Iowa Report 2024**

**Submitted by:** Shelby Gruss, Ph.D., Assistant Professor in Forage Extension, Iowa State University

**Research Activities**

Throughout 2024, I focused on multiple research initiatives to improve forage and grassland management under changing environmental conditions. One significant project involved intercropping alfalfa with summer annuals, such as sorghum-sudangrass and sudangrass, to optimize light penetration and increase yields during the alfalfa establishment phase. This project included three alfalfa varieties and two planting dates (spring and late summer) to assess how different timings affect yield, forage quality, and stand establishment.

In addition, I led research on cover crop integration, evaluating the use of cereal rye and clover planted alongside summer annuals to extend grazing seasons and improve fall forage quality. This study explored different cover crop planting dates and crop combinations, focusing on how cover crops can support forage systems during late-season growth.

Other key projects included looking into alternative traditional corn silage. For example, sorghum silage as a tar-spot resistant alternative and how short-stature corn performs as a silage crop compared to traditional corn silage. Grazing tolerance in alfalfa varieties is also a significant focus, aimed at identifying resilient varieties that can withstand frequent grazing without compromising yield.

**Extension and Outreach Activities**

In addition to my research, I was actively involved in extension and outreach throughout the year, connecting with stakeholders across Iowa and beyond. I delivered presentations at key events, including the McNay Research Farm Hay Day and Forage Field Day.  Additionally, I participate on the RCAP extension team, a vast national network that provides and delivers forage and grassland-based information to producers.

I contributed to numerous newsletters and blogs, providing timely advice to producers on such as forage assessment following flooding, managing hail-damaged alfalfa, and maximizing forage production with summer annuals. These publications reached a broad audience and helped producers navigate the challenges of adverse weather conditions.

Additionally, I was featured in media outlets such as Farm News and Hay & Forage Grower, where I provided expert commentary on forage management practices. These media engagements allowed me to expand the reach of my research and extension activities to a broader audience.

**Extension Highlights:**

* Delivered over 20 presentations at workshops and field days across Iowa and neighboring states, focusing on practical grazing and forage management strategies.
* Published several blog posts and newsletters on forage recovery and maximizing forage production under challenging conditions.

Overall, 2024 was a productive year in terms of research advancements and extension outreach, with a strong focus on enhancing resilience in forage systems and supporting stakeholders with actionable strategies to improve forage production and grazing management.

**Outputs:**

**Journal Articles:**

Gruss, Shelby M., Keith D. Johnson, John Scott Radcliffe, Ronald P. Lemenager, and Mitchell R. Tuinstra. 2024. “Preference of Dhurrin-Free Sorghum by Ewes.” *Crop, Forage & Turfgrass Management* 10 (1): e20259. https://doi.org/10.1002/cft2.20259**.**

***Book Chapters***

1. Moore, Kenneth J. and Shelby M. Gruss, “Structure and Morphology of Grasses.” *Forages, Volume 1*. Edition 8. (in revision).
2. Moore, Kenneth J. and Shelby M. Gruss, “Compendium of Common Forages.” *Forages, Volume 1*. Edition 8. (in revision).

**Extension Outputs:**

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

**Presentations**

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

**Extension Presentations**

1. Gruss, Shelby M. (2024). Planning for Weather Resilience. (Oral Presentation). Water and Fencing Clinic. Western Research and Demonstration Farm, Castana, IA.
2. Gruss, Shelby M. (2024). Winter Feed Strategies. Illinois Beef Association Field Day. (Oral Presentation). Hanover, IL.
3. Gruss, Shelby M. (2024). Optimizing Forage Availability with Cover Crops. (Oral Presentation). Horizon 11 Field Day. McNay Research and Demonstration Farm, Chariton, IA.
4. Gruss, Shelby. (2024). Weed Management in Pastures. (Oral Presentation). Interseeding Sudangrass Field Day. Kirkwood College, Cedar Rapids, IA.
5. Gruss, Shelby. (2024). Weed Management in Pastures. (Oral Presentation). NoFence Grazing Collar Field Day. Breda, IA.
6. Gruss, Shelby M. (2024). US Grazing and Pasture Management. (Oral Presentation). Paraguayan Cattlemen. Ames, IA.
7. Gruss, Shelby. (2024). Managing Organic Rotations for Forage. Organic Field Day. Neely-Kinyon Memorial Research and Demonstration Farm, Greenfield, IA.
8. Gruss, Shelby M. (2024). Optimizing Forage Availability with Cover Crop Grazing. Forage Field Day – Online Edition. Hosted by South Dakota State University and University of Nebraska Lincoln.
9. Gruss, Shelby M. (2024). Hay Management. (Oral Presentation). McNay Hay Day, Chariton, IA.
10. Gruss, Shelby M. (2024). Exploring Tactics with Warm-season annual forage. (Oral Presentation). Iowa Learning Farms. Online.
11. Gruss, Shelby M. (2024). US Grazing and Pasture Management. (Oral Presentation). Korean Cattlemen. Ames, IA.
12. Gruss, Shelby M. (2024). How low can you go? (Oral Presentation). Eastern Iowa Hay Producers, Welton, IA.
13. Gruss, Shelby M. (2024). Forage Selection. (Oral Presentation). Boots in the Barn, Edgewood, IA.
14. Gruss, Shelby M. (2024). Forage Selection. (Oral Presentation). Boots in the Barn, Decorah, IA.
15. Schwabb, Denise, Joshua Michel, and Shelby M. Gruss. (Round table Discussion). Cattle in the Green. Postville, IA.
16. Gruss, Shelby. (2024). Forage Assessment and Conditions Entering Spring. (Oral Presentation). Dairy Team Webinar Series. Online.
17. Gruss, Shelby M. (2024). Pasture Pay in Many Ways. (Oral Presentation). Cornbelt Cow-Calf Conference, Ottumwa, IA
18. Gruss, Shelby M. (2024). Summer Annuals. (Oral Presentation). Cornbelt Cow-Calf Conference, Ottumwa, IA
19. Gruss, Shelby M. (2024). Cultivating Resilience with Warm Season Annual Forage. (Oral Presentation). Iowa Beef Center. Online.
20. Gruss, Shelby M. (2024). Cultivating Resilience: Exploring traits and tactics with warm-season annual forage. (Oral Presentation). Iowa Forage & Grassland Council, Ames, IA,

**Oregon State University**

**NCCC-31 Report 2024 October 7**

***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 such as birdsfoot trefoil, plantain, and chicory 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 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**

***International Collaborative Efforts:*** Continued collaboration in species modeling of response to climate and soil factors with scientists from New Zealand (Lincoln University and Plant & Food Institute) and Australia (APSIM modeling group and University of Tasmania). (David Hannaway).

Collaboration with Caritas’ project in the Republic of Tajikistan: “Public-private partnerships for effective pasture management and risk reduction (Serkan Ates)

Collaboration with Ondokuz Mayis University, Turkiye on a pasture grazing study related to botanical and phytochemical diversity in pastures on forage yield, soil properties and the anthelmintic effect and live weight gain in lambs funded by Scientific and Technological Research Council of Turkiye

***National Collaborative Efforts:*** Collaboration with PRISM Group scientists Chris Daly and Michael Halbleib, world climate center calculations for future species suitability (Scott Bassett (Ecology, Evolution & Conservation Biology Graduate Program, University of Nevada – Reno), and numerous US Extension and research scientists for forage species knowledge. (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 19 topic areas, numerous sub-topics, and content authors. Initial drafts have been completed for many of the sections and a review process is being developed. 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.

**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.

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 Yang, 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).

**State Report (Michigan State University)**

**NCCC-31 Report**

**Federal FY24**

Ecophysiological Aspects of Forage Management

1. Impact Nugget

none

1. New Facilities and Equipment

None

1. 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 2024 we oversaw collection of data from a network of 82 farmers nationwide, including 12 in Michigan. We maintained a website for the project, and planned other Extension assessments and outputs including a Facebook group, and an Extension Bulletin 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* None

*Proceedings publications* None

*Bulletins and Extension Factsheets*

*Online Resources*

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

Ag Resilience. Online 2024. Facebook group. <https://www.facebook.com/groups/989304282540018>

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

*Abstracts , symposium and conference presentations*

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

8. Collaborative Grants *(NCCC31 members bolded)*

* **Cassida, K**, and **S. Gruss**. Nitrogen cycling in biodiverse perennial forage mixtures. Project GREEEN, $98,176. Continuation funding.

9. Graduate students

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

* Jasmine Bontrager (MS, expected May 2025)
* Brandon Scott (MS, expected May 2025)

**State Report (University of Wisconsin – Madison)**

**NCCC-31 Report - Picasso Lab**

Ecophysiological Aspects of Forage Management

* + 1. Impact Nugget

The forages and perennial grains program at UW-Madison consistently grew this year. The NIFA-AFRI-SAS RESILIENCE CAP grant is a collaborative effort of the NCCC31 members and invited colleagues in areas of sociology, economics, and policy. This project is expanding the research, teaching, and extension on forages across Wisconsin and the US.

2. New Facilities and Equipment

None

3. Unique Project Related Findings

Several new papers on intercropping Kernza and perennial legumes for forage and grain production, as well as forage value of agroforestry systems.

4. Accomplishment Summaries

Papers in high impact peer reviewed Journals, including a synthesis paper expanding the framework for diverse perennial circular systems to agroforestry systems, and new results on intercropping perennial grains and forages.

5. Impact Statements

Prevailing agricultural systems dominated by annual crop monocultures, and the landscapes that contain them, lack resilience and multifunctionality. They are vulnerable to extreme weather events, contribute to degradation of soil, water, and air quality, reduce biodiversity, and negatively impact human health, social engagement, and equity. To achieve greater resilience, stability, and multiple ecosystem services therein, and to improve socio- economic outcomes, we propose a practical framework to gain multi- functionality at multiple scales. This framework includes forages within agroecosystems that have the essential structural features of diversity, perenniality, and circularity. These three structural features are associated with increased resilience, stability, and provision of several ecosystem services, which in turn improve human health and socioeconomic outcomes. This framework improves understanding of, and access to, tools and materials for promoting the adoption of diverse circular agroecosystems with perennial forages. Application of this framework can result in land transformations that solve sustainability challenges in agriculture if policy, economic, and social barriers can be overcome by a transdisciplinary process of equitable knowledge production.

6. Published Written Works

*Refereed publications*

Pizarro, D.M., Zarza, R., Boggiano, P., Cadenazzi, M, Picasso, V.D. 2024. Botanical composition gradients in silvopastoral systems on temperate native grasslands of Uruguay. Agroforestry Systems. https://doi.org/10.1007/s10457-024-01027-1

Picasso, V.D. & Pizarro, D. 2024. Silvopastoral transitions in Latin America: toward diverse perennial systems. Agroforestry Systems. https://doi.org/10.1007/s10457-024-01023-5

Pinto, P., Cartoni-Casamitjana, S., Stoltenberg, D.E., and Picasso, V.D. 2024. Forage boost or grain blues? Legume choices shape Kernza intermediate wheatgrass dual-purpose crop performance. Field Crops Research 316:109522. https://doi.org/10.1016/j.fcr.2024.109522

Shoenberger, E.D., Jungers, J.M., Law, E.P., Keene, C.L., DiTommaso, A., Sheaffer, C.C., Wyse, D.L., Picasso, V.D., Stoltenberg, D.E.. 2023. Synthetic auxin herbicides do not injure intermediate wheatgrass or affect grain yield. Weed Technology 37: 560–568. doi: 10.1017/wet.2023.71

Poudel, K., Sheaffer, C., Jungers, J.M., Weihs, B.J., Lamb, J.F.S., Bauder, S., Picasso, V., Heuschele, J., Xu, Z.. 2023. Quantifying winter survival of Alfalfa (Medicago sativa L.). Agronomy Journal, 1–10. https://doi.org/10.1002/agj2.21487

Ashworth, A.J., Marshall, L., Volenec, J.J., Casler, M.D., Berti, M.T., van Santen, E., Williams, C.L., Gopakumar, V., Foster, J.L., Propst, T., Picasso, V.D., and Su, J. 2023. Framework to Develop an Open-Source Forage Data Network to Improve Primary Productivity and Enhance System Resiliency. Agronomy Journal 115, 3062–3073. https://doi.org/10.1002/agj2.21441

DeHaan, L.R., Anderson, J.A., Bajgain, P., Basche, A., Cattani, D.J., Crain, J., Crews, T.E., David, C., Duchene, O., Gutknecht, J., Hayes, R.C., Hui, F., Jungers, J.M., Knudsen, S., Kong, W., Larson, S., Lundquist, P.O., Luo, G., Miller, A.J., Nabukalu, P., Newell, M.T., Olsson, L., Palmgren, M., Paterson, A.H., Picasso, V.D., Poland, J.A., Sacks, E.J., Wang, S., Westerberg, A. 2023. Discussion: Prioritize perennial grain development for sustainable food production and environmental benefits. Science of The Total Environment, p.164975. https://doi.org/10.1016/j.scitotenv.2023.164975

Culman, S., Pinto, P., Pugliese, J., Crews, T., DeHaan, L., Jungers, J., Larsen, J., Ryan, M., Schipanski, M., Sulc, M., Wayman, S., Wiedenhoeft, M., Stoltenberg, D., & Picasso, V. 2023. Forage harvest management impacts “Kernza” intermediate wheatgrass productivity across North America. Agronomy Journal, 115, 2424–2438. https://doi.org/10.1002/agj2.21402

Locatelli, A., Gutierrez, L., Duchene, O., Speranza, P. R., & Picasso, V. D. 2023. Agronomic assessment of two populations of intermediate wheatgrass—Kernza® (Thinopyrum intermedium) in temperate South America. Grassland Research, 1(4), 262–278. https://doi.org/10.1002/glr2.12032

7. Scientific and Outreach Presentations

*Abstracts, symposium and conference presentations*

Akins, M.S., J.S. Cavadini, K.G. Wells, D.M. Pizarro, V.D. Picasso, M.A. Wattiaux. 2024. Effect of nitrogen fertilization on yield and nutritive value of fall-stockpiled tall fescue, meadow fescue, or orchardgrass. ADSA Annual Meeting. June 16-19th 2024. West Palm Beach, Florida, USA.

Olugbenle, O., & Picasso, V. D. 2023. Yield and Forage Quality of Dual-Use Populations of Intermediate Wheatgrass Intercropped with Legumes [Abstract]. ASA, CSSA, SSSA International Annual Meeting, St. Louis, MO. https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/149197

Shoenberger, E., Stoltenberg, D., & Picasso, V. 2023. Does N fertilization and thinning maintain Kernza yields overtime? Flash talk and poster presentation at the American Society of Agronomy Conference, Saint Louis, MO

Shoenberger, E., Picasso, V., & Stoltenberg, D. 2023. Addressing the knowledge gap of herbicide effects on Kernza intermediate wheatgrass growth, development, and grain yield. Poster presentation at the Kernza Conference, Minneapolis, MN

Olugbenle, O., Ginot, C., Duchene, O., & Picasso, V.D. 2023. Effects of plant density and row spacing on Kernza yield components (Preliminary results). International Kernza Phisiology symposium. Madison, WI.

Pizarro, D.M., D.A. Plata-Reyes, C.G.Martínez-García, C.A. Gómez-Bravo, V.D. Picasso, and M.A. Wattiaux. 2024. Perception of changes in agroecological practices of dairy farms by smallholders in Peru and Mexico. ADSA Annual Meeting. June 16-19th 2024. West Palm Beach, Florida, USA.

\*Picasso, V.\*; Williams, C.\*. 2023. A transdisciplinary approach to landscape transformation towards perennial, diverse, circular systems: why and how. XXV International Grasslands Congress, Covington, KY, USA, May 14-19, 2023

8. Collaborative Grants

Current grants:

Fostering Resilience and Ecosystem Services Across Landscapes by Integrating Diverse Perennial Circular Systems. USDA NIFA SAS CAP. $10,000,000 (PI: Picasso – UW-Madison)

Breeding Alfalfa for Intercropping with Intermediate Wheatgrass: Towards perennial grain-forage systems. USDA-NIFA- AFRP. $800,000 (PI: Moore- Cornel U)

Developing and deploying a perennial grain crop enterprise to improve environmental quality and rural prosperity. USDA NIFA SAS CAP. $10,000,000 (PI: Jungers -UMN)

9. Graduate students

Olugakorede Olugbenle PhD Agronomy Kernza agronomy

Dante Pizarro PhD Dairy Science Kernza feed value & silvopasture

Soledad Orcasberro PhD Agronomy Alfalfa in dairy and soil health

Erica Shoenberger PhD Agronomy Kernza soil health and farmers

Angad Dhariwal MSc Agroecology Intercro

**State Report (University of Wisconsin – Madison)**

**NCCC-31 Report - Kohmann Lab**

Ecophysiological Aspects of Forage Management

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; and [2] Wheel traffic effects on alfalfa-corn interseeded systems.

1. **New Facilities and Equipment**

None.

1. **Unique Project-Related Findings**

Soil respiration, which includes soil microbial respiration and root respiration, is reduced in alfalfa fields areas affected by wheel traffic.

1. **Accomplishment Summaries**

During 2022-2023, two projects were initiated: [1] A litterbag decomposition study, and [2] A study evaluating wheel traffic effects on alfalfa persistence in alfalfa-corn interseeded systems. The litterbag study will evaluate nutrient cycling from alfalfa shoots and roots in fall and spring, as well as with and without manure application. We will be able to quantify amount of nitrogen and phosphorus from alfalfa termination to subsequent crops, while also understanding how manure application might affect nutrient mineralization. Our wheel traffic study initiated this summer will evaluate how traffic from different machinery types (typically used in farm operations) will affect alfalfa persistence and production. Both studies will be concluded in 2025.

1. **Impact Statement**

[1] Litterbag study: Initial results indicate decomposition rate is greater when alfalfa is terminated in the spring compared to fall, likely because of greater temperatures and rainfall. We also observed greater decomposition rates from alfalfa shoots compared to roots.

[2] Wheel traffic: We noted an immediate negative effect on soil health, estimated with soil respiration as a proxy. This change in soil health seems to be more closely related to damages on alfalfa plants than to soil characteristics affect by wheel traffic.

1. **Published Written Works (**selectedpeer-reviewed and outreach-oriented**)**

Sollenberger, L.E., **M.M. Kohmann**. 2024. Forage legume responses to climate change factors. Crop Science 64, 2419-2432. doi: 10.1002/csc2.21304

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. Target Journal: Weed Science (Submitted).

*Outreach publications:*

Forage Focus:

Grazing Pastures in the Midwest: Is a Weed really a Weed? **Marta Kohmann**, Mark Renz, Arthur Duarte, Jason Cavadini, Bill Halfman, and David Jaramillo. Forage Focus. MFA Updates, March Issue.

Corn-Alfalfa Interseeding Shines in Large Scale UW Madison Trials. Scott Newell, **Marta Kohmann**, and Mark Renz. Forage Focus. MFA Updates, December Issue.

1. **Scientific and Outreach Presentations**

o 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.

o 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.

o 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.

o 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.

o 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.

o 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.

o 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.

o 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.

1. **Graduate Students**

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

**Ohio Report 2023-2024 (The Ohio State University)**

**NCCC-31 Report**

Ecophysiological Aspects of Forage Management

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.

1. New Facilities and Equipment

* CT 293 Cyclotec Mill
* 2023 Chevy Equinox

1. 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.

1. Accomplishment Summaries

Native warm season grasses to enhance pasture resilience to climate change

This project aimed to identify effective management practices for establishing native warm-season grasses (NWSG) in pastures at four locations in Ohio: Jackson, Caldwell, Flushing, and Georgetown. The primary objective was to evaluate the morphogenic and structural characteristics of NWSG species under different establishment strategies. Results showed that organic management failed to establish NWSG, even after two years of experimental trials. Inorganic establishment was successful but varied significantly across regions. The study also explored the relationship between warm-season grasses and arbuscular mycorrhizae fungi (AMF), comparing it with the relationship between cool-season grasses and AMF. We quantified AMF colonization rates in three NWSG species (switchgrass, big bluestem, and Indiangrass), three cool-season grass species (tall fescue, orchardgrass, and Kentucky bluegrass), and one legume (white clover). All species were grown in a greenhouse for nine months under different cutting frequencies to simulate varying grazing strategies. Cutting frequencies were based on leaf availability in the upper, grazeable stratum, which varied by species due to their different growth rates.

The results indicated that cutting frequency did not affect AMF colonization. On average, lower cutting frequency (every 26 days) resulted in 32% AMF colonization, while higher cutting frequency (every 17 days) also resulted in 32%. However, species-specific differences in AMF colonization were observed. White clover had the highest AMF colonization at 76%, followed by orchardgrass at 50%. In contrast, switchgrass and Kentucky bluegrass showed the lowest AMF colonization rates at 12% and 11%, respectively. Additionally, colonization by other fungi (endophytes) was measured, including cases where no colonization was observed.

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

The objective of this research was to evaluate optimally managed forage species with complementary traits as an alternative to the conventionally used fescue-clover pastures. A pilot greenhouse study examined two contrasting defoliation frequencies across six common forage species in Ohio—tall fescue, orchardgrass, Kentucky bluegrass, indiangrass, and big bluestem. The defoliation treatments were: 1) frequent, when the plant canopy intercepted 95% of incoming light, and 2) infrequent, when the canopy reached maximum light interception. This experiment, conducted in Columbus, OH, from December 2022 to August 2023, used a factorial completely randomized design (CRD) with 36 experimental units (three replicates for each combination of six species and two defoliation frequencies). The upcoming field experiment will evaluate three plant mixtures grazed under the same contrasting defoliation protocols identified in the greenhouse study (frequent and infrequent) and two soil conditions (prone to inundation and not prone to inundation). The plant mixtures include: a conventional tall fescue-clover mix, a cool-season mix (fescue + white clover + orchardgrass + bluegrass), and a warm-season mix (big bluestem and Indiangrass). This split-plot, randomized complete block design (RCBD) field experiment will be conducted from 2024 to 2025. Measurements will include forage growth rate, nutritional content, and botanical composition. Animal responses will be assessed by measuring plant selectivity, grazing efficiency, and in-vitro methane emissions from available forage.

1. 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

In this study, frequent defoliation resulted in shorter swards with higher leaf accumulation rates, while infrequent defoliation led to taller plants but with lower leaf accumulation rates. Target heights for both defoliation frequencies were determined for all species and will serve as a foundation for guiding an upcoming field study. This approach integrates planned plant diversity and strategic grazing management to build resilience against environmental disturbances.

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.*

Chiavegato, M.B. 2023. The role of roots on C sequestration in agricultural fields. *The Journal of Nutrient Management*. February 2023.

Chiavegato, M.B. 2023. The connection between nutrient management and climate change. *The Journal of Nutrient Management.* May 2023.

Miquilini, M., Ribeiro, R.H., Bauman, S., Lyon, S.W., Chiavegato, M.B. 2023. Higher apical meristem in tall fescue as adaptation strategy to recurring short-term inundation in Ohio. *Agrosystems, Geosciences and Environment. In press.*

Ribeiro, R.H., Miquilini, M., Lyon, S.W., Dieckow, J., Chiavegato, M.B. 2023. Effects of recurring inundation on diversified pastures forage and root biomass and on particulate organic matter stocks. *Grass and Forage Science*. https://doi.org/10.1111/gfs.12643

Kannberg, S., Lindsey, A.J., Chiavegato, M.B., Lindsey, L.E. 2023. Effects of soybean planting date on soybeans grain yield within a rye cover crop system. *Agronomy Journal*. *In press.*

Silva-Pumarada, G., Shrestha, R.K., Chiavegato, M.B., Mercer, K., Agyei, B.K., Singh, M.P., Lindsey, L.E. 2023. Effect of biochar application on corn and soybean yield in Michigan and Ohio. *Crop, Forage & Turfgrass Management*. https://doi.org/10.1002/cft2.20245

7. Scientific and Outreach Presentations

*Abstracts, symposium and conference presentations*

1. Mammana, F.A., Chiavegato, M.B. 2023. Identifying Grazing Targets for Improved Forge Quality in Ohio. 16th Annual Horticulture & Crop Science Research Symposium, Wooster, OH.
2. Stachler, C., Mammana, F.A., Chiavegato, M.B. 2023. Associated Effects of Grazing and Flooding on Greenhouse Gas Emissions in Southern Ohio. 16th Annual Horticulture & Crop Science Research Symposium, Wooster, OH.
3. Rodriguez, C., Chiavegato, M.B. 2023. Arbuscular Mycorrhizal Fungi a Hidden Tool to Improve Forage Growth and Quality. 16th Annual Horticulture & Crop Science Research Symposium, Wooster, OH.
4. Mammana, A.F., Stachler, C., Chiavegato, M.B. 2023. Identifying Grazing Targets for Improved Forage Quality in Ohio. [Abstract]. ASA, CSSA, SSSA International St Louis, MO.
5. Ribeiro, R.H., Lyon, S.W., Haden, V.R., Jackson-Smith, D., Chiavegato, M.B. 2023. Effects of Manure Application on Greenhouse Gas Emissions Under Crop-Livestock Integration. [Abstract]. ASA, CSSA, SSSA International St Louis, MO. <https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/149208>
6. Ribeiro, R.H., Chiavegato, M.B. 2023. Soil Carbon Stocks Under Perennial Grasslands and Hayfields: An on-farm Assessment in Ohio. [Abstract]. ASA, CSSA, SSSA International St Louis, MO. <https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/149210>
7. Stachler, C., Mammana, A.F., Chiavegato, M.B. 2023. Associated Effects of Grazing and Inundation in Greenhouse Gas Emissions in Southern Ohio. [Abstract]. ASA, CSSA, SSSA International St Louis, MO. <https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/149257>
8. Mammana, F.A., Chiavegato, M.B. 2023. Identifying Grazing Targets for Improved Forge Quality in Ohio. 16th Annual Horticulture & Crop Science Research Symposium, Wooster, OH.
9. Stachler, C., Mammana, F.A., Chiavegato, M.B. 2023. Associated Effects of Grazing and Flooding on Greenhouse Gas Emissions in Southern Ohio. 16th Annual Horticulture & Crop Science Research Symposium, Wooster, OH.
10. Rodriguez, C., Chiavegato, M.B. 2023. Arbuscular Mycorrhizal Fungi a Hidden Tool to Improve Forage Growth and Quality. 16th Annual Horticulture & Crop Science Research Symposium, Wooster, OH.
11. Chiavegato, M.B., Mammana, A.F., Rodriguez, C.Y. 2023. Productive Grasslands – The Role of Adapted Species to Increase Ecosystems resilience. [Abstract]. International Grassland Congress, Covington, KY.

8. Collaborative Grants

1. 9/2023. Long-term effects of composed biochar on soil health, crop yields, and greenhouse gas emissions in an integrated crop-livestock system. The Greenacres Foundation ($317,857). PI: Chiavegato, M.

9. Graduate students

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

Verhoff, Kyle. MS. Graduation date March 2023. A rotational stocking strategy to maintain pasture sward heights for optimizing sheep and forage responses.

Ribeiro, Ricardo Henrique. PhD. Graduation date February 2023. Soil carbon inputs and storage in flooded pasture fields of Southern Ohio.

Rodriguez, Chelsie. MS. Expected graduation date December 2023. Native warm-season grasses in Ohio – Implementation protocol and productive response to arbuscular mycorrhizal fungi.

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

Salsbury, Lydia. Expected graduation date December 2026. 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.