**APPENDIX D SAES-422**

**Multistate Research Activity**

**Accomplishments Report**

**Project/Activity Number:** NCCC-31

**Project/Activity Title**: Ecophysiological Aspects of Forage Management

**Period Covered:** June 2020 to May 2021

**Date of This Report:** September 20, 2021

**Annual Meeting Date(s)**: Virtual, 21-22 July 2021

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

|  |  |  |  |
| --- | --- | --- | --- |
| **State** | **Attending members** | **Institution** | **Reported remotely** |
| AR |  | USDA-ARS | Amanda Ashworth |
| IN |  | Purdue University | Jeff Volenec |
| KY |  | University of Kentucky | Rebecca McCulley |
| MA |  | University of Maryland | Bill Lamp, Amanda Grev |
| MI |  | Michigan State University | Kim Cassida, Jim Kells (administrator) |
| NE |  | University of Nebraska | John Guretzky |
| ND |  | North Dakota State University | Marisol Berti |
| OH |  | The Ohio State University | Mark Sulc, Marilia Chiavegato |
| OR |  | Oregon State University | Guojie Wang |
| TN |  | University of Tennessee | Renata Nave Oakes |
| TX |  | Texas A&M | Jamie Foster |
| UT |  | Utah State University | Jennifer McAdam |
| WI |  | Univ. of Wisconsin, ARS-USDA | Valentin Picasso, John Grabber |
| WY |  | University of Wyoming | Anowar Islam |

**Activities:**

|  |  |
| --- | --- |
| **Wednesday July 21 (CDT)** | **Thursday July 23 (CDT)** |
| 10:00 Welcome, announcements, and updates | ***10:00 – 10:30 State reports (Cont.)*** |
| ***10:10 - 1:55 State reports*** | 10:00 Kentucky – Rebecca McCulley |
| 10:10 Arkansas - Amanda Ashworth | 10:10 Wisconsin - Valentin Picasso, John Grabber |
| 10:30 Indiana – Jeff Volenec | 10:30 Jim Kells, Michigan State University |
| 10:40 Maryland - Bill Lamp & Amanda Grev | 10:40 Jim Dobrowolski (NIFA Representative update) |
| 11:00 Michigan - Kim Cassida | ***Business Meeting*** |
| 11:20 Nebraska - John Guretzky | - Annual report |
| ***11:30 Coffee Break/lunch break*** | - Next meeting location |
| 12:15 North Dakota - Marisol Berti | - Incoming chair and vote for new secretary |
| 12:25 Ohio - Marilia Chiavegato | - Updates on NIFA SAS grant (Valentin Picasso) |
| 12:45 Oregon - Guojie Wang | 11:30 Phenological Development Project Discussion (David Hannaway, Kim Cassida, Jeff Volenec) |
| 12:55 Texas - Jamie Foster | 12:30 Adjourn |
| 1:05 Tennessee - Renata Nave Oakes |  |
| 1:15 Utah - Jennifer MacAdam |  |
| 1:25 Wyoming - Anowar Islam Adjourn |  |
| 1:35 Adjourn |  |

\* Planned meeting and field visit planned in Laramie, WY was cancelled due to COVID-19.

**Business meeting minutes**

- Twenty participants.

- State report presentations: Arkansas, Indiana, Kentucky, Maryland, Michigan, Nebraska, North Dakota, Ohio, Oregon, Texas, Tennessee, Utah, Wyoming, and Wisconsin.

- Updates by NIFA Representative: new program areas, funding opportunities, and updates in AFRI and NIFA.

- Discussion about a new project on phenological development, David Hannaway, Kim Cassida and Jeff Volenec.

- Committee is in good standing and is perceived to be a productive committee.

- Discussions on the collaborative submitted SAS proposal led by Valentin Picasso.

- Next meeting tentative location: Laramie, WY (since travel was not permitted in 2021). Host: Wyoming- Anowar Islam.

- Goujie Wang incoming chair: 2021; Valentin Picasso incoming secretary.

**STATE REPORTS**

**NCCC31- Ecophysiological Aspects of Forage Management, 2021 Report**

**Arkansas Report 2020-2021**

**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 annuals, perennials, warm and cool season forages, including native species. We have extending our activities into the areas of determining N fluxes in pastures and measuring N-use efficiencies across the soil-plant-animal interface. We have also started to work in the area of agroforestry and silvopasture applications and continue to cooperate with university and USDA research stations and private landowners state-wide.

1. **New Facilities and Equipment**

Members of our forage research group engage in sheep research, currently with in-house feeding and supplement trials. We started to establish paddocks (total of 20, 0.25-0.5 ha in size) in a smaller bermudagrass pasture and larger novel endophyte tall fescue pasture to efficiently rotate and conduct field research in the long-run. Four trees were planted in each paddock (total of 80) in fall of 2020 to provide long-term shade for livestock. Tree species were selected with help from a collaborator and included oak, sycamore, maple, cypress, and mulberry. We were able to acquire several soil probes to simultaneously measure moisture, temperature, and electric conductivity which we are using in a silvopasture project to evaluate establishment success and production of cool season perennial forages in a thinned hardwood forest.

1. **Unique Project-Related Findings**

Unexpected findings were made with regard to establishment success and persistence of forages established in wooded areas. Established tall fescue and orchardgrass were only little affected by woody, low-growing vegetation that was removed prior to planting. Groundcover from both grasses held back other vegetation from establishing much better than expected. Both tall fescue and orchardgrass fully remained in the vegetative stage and did not produce reproductive tillers. This finding (probably reported elsewhere by others) indicated that forage nutritive value remains high during the typical growing season, although forage was not harvested by either grazing or mowing.

1. **Accomplishment Summaries**

During 2020-2021, two agroforestry-related projects were continued: 1) assessment of annual and perennial forages in thinned pine tree plantations and 2) establishment of perennial forages in a thinned native hardwood forest. Forages were selected based on previous research and experience from participating landowners. We continued a NIFA-funded project on the effects of tannin-containing silage diets on sheep intake and soil quality parameters and ammonia emissions after the application on native warm-season grasses of collected urine and feces resulting from this study. Plots were established in a native grass (big bluestem, indiangrass, and little bluestem) pasture to which sheep urine and feces were applied to test for leaching, ammonia emissions, and various soil biochemical and physical parameters. This study was concluded in early fall of 2020 and a full data analysis is under way.

1. **Impact Statement**

**Issue:**

Grazing systems resiliency is important for long-term sustainability of grassland agriculture. Arkansas is covered with wooded areas by 60% and opportunities exists to establish silvopastoral systems for enhanced diversity and income from timber and animal products. The high likelihood of changing climatic patterns will also require finding solutions to mitigate adverse effects from increasingly dry and hot summers. Silvopasture systems may offer the opportunity for cattle grazing with lower ambient temperatures yet sufficient forage growth in alleyways.

**Action:**

In 2019, we secured multi-year funding to evaluate establishment strategies and persistence of forages grown under silvopastoral conditions. Eight commonly used forages were selected including perennial, annual, grass, and legume species to monitor growth and environmental dynamics in pine tree alleys located in the Arkansas River Valley. Plots were established in October of 2019 and will be replanted and maintained for another 2-3 years. In addition to small-plot-research, we are working with landowners and producers to establish demonstrations and limited research in thinned forests on their properties with the goal of making our results highly accessible to the public. In fall of 2020 we established a set of silvopasture demonstration plots on a cooperator farm and proceeded with reestablishing annual forages in pine tree stands. We also added a substantial soil research aspect to our project and were able to bring in a graduate student. As a result, we started a comprehensive root growth experiment and installed monitoring cores in selected hard wood silvopasture forage plots (~50) to evaluate fine root accumulation to a depth of 30 cm.

**Impact:**

This multi-year project serves as a testing ground for shaping silvopastoral systems that are sustainable and resilient due to their multi-use components. Our project provides information on the resilience of a variety of forage species and strategies for a multi-purpose use of wooded areas and grazing grounds.

**Contact:**

Dirk Philipp, Department of Animal Science

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

Cooperators: C. Nieman, J. Franco (USDA-ARS, Booneville, AR)

**Funding: This project is being realized with appropriations from USDA-Southern SARE.**

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

Christine C. Nieman, **Kenneth P. Coffey, Elizabeth B. Kegley, P. Hornsby**, J. Hollenback, **Dirk Philipp**. 20XX. *Supplementation of different sources and heating of dried distillers grains for lactating beef cows consuming bermudagrass hay*. Submitted (J. Anim. Sci.)

Niyigena, V., **Coffey, K. P**., Coblentz, W. K., **Philipp, D**., Althaber, C., Diaz Gomez, J., **Rhein, R. T**., Pruden, M. C. 20XX. *Intake, digestibility rumen fermentation and nitrogen balance in sheep offered alfalfa and tall fescue-mixtures harvested and ensiled after a killing frost*. Submitted (Anim. Feed Sci. Technol.)

Niyigena, Valens, Ashworth, Amanda J, Nieman, Christine, Acharya, Mohan**, Coffey, Ken, Philipp, Dirk**, Meadors, Lillian, Sauer, Tom. 20XX. *Factors affecting sugar accumulation and fluxes in warm- and cool-season forages grown in a silvopastoral system*. Submitted (Crop Sci.)

Amanda J. Ashworth, Tulsi Kharel, Phillip R. Owens, Taylor C. Adams, **Dirk Philipp**, Andrew L. Thomas, and Tom Sauer. 20XX. *Determining how spatially variable landscape attributes impact preferential grazing in silvopasture systems*. Submitted (Nature Communications)

A.J. Ashworth, T.C. Adams, T.P. Kharel, **D. Philipp**, P. Owens, and T. Sauer. 20XX. *Forage Root Decomposition in Silvopastoral Systems Influenced by Soil Moisture, Grazing, Fertilization, and Grass Species*. Submitted (Archives of Agronomy and Soil Science).

**V. Niyigena, K. P. Coffey,** W. K. Coblentz, **D. Philipp, R. T. Rhein**, J. D. Caldwell, and B. C. Shanks. 20XX. *Nitrogen balance and blood urea nitrogen by gestating sheep offered alfalfa silage wrapped with or without an enhanced oxygen barrier plastic after time delays up to three days*. Submitted (Small Ruminant Research).

*Abstracts:*

Adams, T.C., Ashworth, A., Kharel, T**., Philipp, D**., Owens, P., Sauer, T., Agroforestry Symposium, "Forage root decomposition in Silvopastoral systems is influenced by grazing, fertilization, and grass species," University of Missouri.

Ashworth, A., Niyigena, V., Nieman, C., Acharya, M., **Coffey, K.,** **Philipp, D**., Meadors, L., Adams, T., Sauer, T., ASA-CSSA-SSSA Annual Meeting 2020, "Water soluble carbohydrate accumulation and fluxes in warm- and cool-season forages grown in a silvopastoral system." (2020).

Nieman, C.C**., D. Philipp, K.P. Coffey**, and J.G. Franco. 2020. Cowpea sown with sorghum-sudangrass and baled at two moisture levels for greater baleage nutritive value. AFGC annual meeting Greenville, SC

**Kennedy, I., Savin, M., Philipp, D., Coffey, K., & Zhao, J.** (2020). *Nitrogen leaching in pasture soil receiving excretions from sheep consuming tannin containing legumes*. In: ASA-CSSA-SSSA Annual Meeting Program. ASA and CSSA, Madison, WI.

*Outreach publications:*

Factsheets:

**Jennings, J., Simon, K., & Philipp, D.** (2020). *Planting Oats for Forage*. UA Division of Agriculture.

FSA3151

ANSC E-News:

**Philipp, D.** (2020). *What can silvopastures do for you?*. UA Division of Agriculture.

Dairy E-News:

**Philipp, D.** (2020). *Expanding grazing areas on forested properties*. UA Division of Agriculture.

Arkansas Beef and Forage Corner:

**Philipp, D.** (2020). *Riparian management during winter time*. Arkansas Cattle Business.

Forage/Beef Cattle Tips:

Recurring monthly postings on forage management (**Simon, Jennings, Philipp**)

Popular Press/Other Media Outlets (outlets in addition to uaex.edu website):

Philipp, D., Hightower, M. (2020). *Bermudagrass management*. UA Division of Agriculture.

Philipp, D., Hightower, M., (2020) *Ranchers can help grassland birds rebuild populations*

Philipp, D., Hightower, M. (2020) *Riparian buffer especially sensitive during winter grazing*

Philipp, D., Hightower, M. (2020). *Expectations for silvopastures*. UA Division of Agriculture.

Philipp, D., Hightower, M. (2020). *Forage winter grazing*. UA Division of Agriculture.

Philipp, D., Hightower, M. (2020). *Horse pasture management*. UA Division of Agriculture.

Philipp, D., Hightower, M. (2020). *Mutual benefits of sheep and shade trees*. UA Division of

Philipp, D., & Hightower, M. (2020). *How to avoid overgrazing pastureland*. . Published.

Philipp, D., Hightower, M. (2020). *Native grass management during winter*. UA Division of

Philipp, D., Hightower, M. (2020). *Reviving pastures*. UA Division of Agriculture.

*Video material (research-relevant):*

* + Summary of agroforestry research activities (1 video)
    - USDA-ARS Ames, IA; USDA-ARS Fayetteville, and UA Division of Agriculture cooperation
* Active USDA-SARE grant-related (throughout the entire year)
  + Continued to collect video footage on establishment of silvopastoral systems (site preparation, planting)
  + Video interviews with contracted timber consultant and cooperating landowner
  + Locations in Subiaco and Booneville
  + Footage will be used to produce educational videos as specified under grant objectives

1. **Scientific and Outreach Presentations**

Philipp, D., Beef and Forage Seminar I, "Old Word Bluestems in North America: History, Production, and Opportunities for Livestock Producers," University of Missouri, Annual, West Plains, MO. (March 9, 2020).

Philipp, D., Beef and Forage Seminar II, "Old world bluestems in North America: History, Production, and Opportunities for Livestock Production," University of Arkansas, Mountain Grove, MO. (March 10, 2020).

Philipp, D., Webinar - Cattle Production Workshop, "Pasture Production - Cattle Production Workshop," University of Arkansas - Pine Bluff, Online. (October 6, 2020).

1. **Collaborative Grants**

Newly awarded:

* Rupp, S. et al. (Philipp Co-PI): A holistic, cost-effective approach for reinvigorating practice 360 (waste facility closure) for poultry houses in Northwest Arkansas.
  + USDA-NRCS/CIG, $150,000
* Morris, M. et al. (Philipp Co-PI): Soil for Water.
  + USDA-Southern SARE; $1,000,000
* 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

1. **Graduate Students**

* Matt Janorschke, MS Student co-advised with Dr. Mary Savin (Univ. of Arkansas, Crop and Environmental Sciences)

**Arkansas Report 2020-2021**

**USDA-ARS, Fayetteville, AR**

1. Impact Nugget:

The USDA-ARS Unit, located at the University of Arkansas, conducts research and technology transfer on practices that reduce negative environmental impacts of poultry litter on air, soil, and water resources, while improving the agronomic value of this resource in pasture agroecosystems.

2. New Facilities and Equipment:

Volumetric Water Content (VWC) sensors, drone (NDVI and multi-spectral), and an electrical conductivity (EC) meter were procured to attain research-quality accuracy in measurement of soil-water in an integrated agroforestry-animal grazing system.

3. Unique Project Related Findings:

1. Animal manures, which are valuable sources of nutrients, may also contain antimicrobial resistant (AMR) genes. Following 14-years of continuous pasture management, AMR genes in grassland soils following 14-years of poultry litter and cattle manure deposition were evaluated. Continuous grazing (relative to conservation best management practices such as rotation grazing) had the greatest abundance of AMR genes, thus suggesting overgrazing and continuous cattle manure deposition may increase AMR gene presence. Results suggest that conservation pasture management practices may minimize the presence and number of AMR genes in grassland soils.

2. Systems-level studies aimed at determining how soil properties are linked to plant production and ultimately animal response are lacking. A study was carried out to identify if grazing pressure is linked to soil properties, terrain attributes, and aboveground plant accumulation and nutritive value using GPS cattle tracking devices. Cattle avoided grazing areas with deeper soils (i.e. > 100 cm), which corresponded to reduced elevation and increased soil moisture spatially. Combining spatial behavioral monitoring technologies with pasture availability may improve grazing systems management spatially and temporally.

4. Accomplishment Summaries:

Quantified best management practice effects on soil health. A series of experiments set out to identify long-term (>15 years) conservation practices influence on soil quality, as understanding the impacts of long-term agricultural practices on soil quality is key for sustaining agroecosystem productivity. Researchers at the Fayetteville, AR; Booneville, AR; and Lincoln, NE units and University of Arkansas and the Federal Rural University in Lavras, Brazil used the Soil Management Assessment Framework to quantify soil health in grassland, cropping, and agroforestry systems. Researchers found that practices such as animal manure applications, non-tillage, crop rotations, and rotational grazing improved soil quality relative to business-as-usual practices (e.g. monocropping, tilled, and inorganic fertilizer management). Soil health improvements corresponded to increased carbon storage, primary productivity, and water quality improvements, which underlines the benefits of conservation soil management in diverse circular systems.

Identified alternative management practices to ensure long-term sustainable use of poultry litter. Broiler (meat chicken) production in the southeastern US is a leading enterprise totaling $31.7 billion USD in agricultural receipts, with about half of the production occurring in four southeastern states. The use of by-products from poultry production, or poultry litter, has the potential to close nutrient loops, as by-products are re-applied the following season to marginal soils. Although, conventional application methods entail spreading poultry litter on the soil surface, which can result in up to 60% of nutrients being lost to the air, soil, and water. In efforts to improve management options that aid in nutrient sustainability and improve crop yield, an ARS research team developed an implement for subsurface applications of poultry litter in conservation tillage systems. This ‘Subsurfer’ lowers nutrient runoff and ammonia emissions by 90%. This practice was compared to poultry litter surface applications in small watersheds. Researchers found that the ARS Subsurfer reduced nutrient losses in runoff by 66% and improved crop yields by 39%. Therefore, subsurface incorporation of poultry litter relative to surface applications of poultry litter can enhance soil and water conservation and improve crop yields.

Identified practices that minimize the spread of antibiotic resistant gene movement in the environment. Veterinary pharmaceutical usage is an essential component of treating infections in poultry and bovine production. Manure from treated animals, which is an abundant source of valuable nutrients, may also contain antimicrobial resistant (AMR) bacteria. The existence of AMR bacteria in soil and water is a significant public health concern. According to the Organisation for Economic Cooperation and Development, 2.4 million people will die from infections with resistant microorganisms in the next 30 years, costing up to 3.5 billion USD per year. Yet the fate and transport pathways from animals to the environment is poorly understood in the largest U.S. land-use category, or grasslands. A series of studies tracked the movement of AMR bacteria following animal manure (cow and poultry) land applications. After 14-years of continuous management, AMR bacteria were greatest under continuous grazing (relative to conservation best management practices), suggesting continuous cattle manure deposition may increase AMR gene presence. In general, AMR genes increased downslope, suggesting potential lateral movement and accumulation based on landscape position. Researchers found that poultry litter had lower abundance of AMR bacteria relative to cattle manure. Adoption of conservation pasture best management such as riparian buffer strips improves water quality while disrupting AMR bacteria movement, which will contribute positively to disease management.

Developed a method for rapidly quantifying spatial overlaps and gaps for precision agriculture tools in pastures. Scientists from Fayetteville and Booneville, Arkansas and University of Arkansas research partners developed an automated method for rapid determination of spatial coverage of precision agriculture technologies, such as auto-guided tractors and other self-propelled machinery that reduce over-application of on-farm nutrients and inputs by 10-20%. It is estimated that auto-guided tractors reduce on-farm inputs by as much as 20% and can save producers $10.8-13.5 million annually by improving gains in equipment efficiency and enhancing yields. Moreover, producers can also reduce the over-application of fertilizers and herbicides, which reduces the negative environmental footprint of crop production and avoids unintentional input costs to the producer. Currently, roughly half of large-scale row crop producers are using tractor guidance, however, 82% of the total farms in the US are small farms but are largely not adopting these cost and environmental saving technologies. Therefore, this team: 1) developed a method to calculate overlaps and gaps, and 2) quantified overall gains by tractor guidance systems. Field research was conducted using fertilizer (inorganic and poultry litter) and sprayer applications with and without tractor guidance. USDA-ARS researchers developed a novel automated method for quantifying overlaps and gaps and proposes a new method for calculating spatial coverage efficiency. Results suggests that tractor guidance systems reduce overlaps (up to 6% of the total field area) and gaps (up to 16%) during field operations and improves the average overall efficiency by 8%. Hence, tractor guidance systems likely result in reduced input-use and shorter in-field operation time leading to improved economic and environmental savings. Our approach to estimate tractor guidance efficiency on small farms using actual field research is novel and may aid in adoption of tractor guidance, thus potentially improving efficiency gains on 82% of US farms.

5. Impact Statements

During 2020-2021, Arkansas (USDA-ARS, Ashworth et al.) published data on BMPs for reducing nutrient losses and antibiotic resistance, while improving forage production and soil health in pasture systems at the soil-plant-water nexus. Outreach activities included the delivery of our findings during in-service training sessions, field days, and through technology transfer. A summary of all publications and funding procured from 2020-2021 is included at the end of this document. Selected project impacts are listed above in detail.

1. Developed a management recommendation for an ARS implement that minimizes nutrient losses to the air, soil, and water in silage systems.

2. Developed a method for rapidly quantifying spatial overlaps and gaps for precision agriculture tools in pastures.

6. Published Written Works

*Refereed publications*

Rocateli, A.C., A.J. Ashworth, C.P. West, K.R. Brye, M. Popp, and J.R. Kiniry. 2020. Simulating switchgrass biomass productivity using ALMANAC. I. Calibration of soil water. Agronomy Journal. 112: 183– 193. doi: 10.1002/agj2.20054

Ashworth, A.J., K. V. Knapp, F.L. Allen, and A.M. Saxton. 2020. Comparing yield trial locations based on their elicited expressions of genetic variance among soybean cultivars. Crop Sci. 60:1313–1324. doi:10.1002/csc2.20066

Ashworth, A.J., P.R. Owens, and F.L. Allen. 2020. Long-term cropping systems management influences soil strength and nutrient cycling. Geoderma. 361. 114062, doi:org/10.1016/j.geoderma.2019.114062

Anderson, K., P.A. Moore, Jr., C. Pilon, J. Martin, D.H. Pote, P.R. Owens, A.J. Ashworth, D. Miller, and P. DeLaune. 2020. Long-term study on the effects of buffer strips and grazing management on phosphorus runoff from pastures. J. Environ. Qual. 49: 85– 96. doi:10.1002/jeq2.20010

Acharya, M., B.S. Howell, J. Burke, A.J. Ashworth, and R.W. Rorie. 2020. Relationship of anti-mullerian hormone to reproductive traits in katahdin ewes bred in late spring or fall. Advances in Reproductive Sciences. 8: 48-56. doi: 10.4236/arsci.2020.81005

Ashworth, A.J., D.H. Pote, D.B. Watts, and T.R. Way. 2020. Effect of seeding distance from subsurface banded poultry litter on corn yield and leaf greenness. Agronomy Journal. 112:1679–1689. doi: 10.1002/agj2.20186

Ashworth, A.J., P.A. Moore, Jr., R. King, J.L. Douglas, D.H. Pote, and A.A. Jacobs. 2020. Switchgrass nitrogen fertility response and nutrient cycling in a hay system. Agronomy Journal. 112:1963–1971. doi:10.1002/agj2.20156. 2020

Amorim, H.C.S., A.J. Ashworth, B.J. Wienhold, M.S. Savin, F.L. Allen, A.M. Saxton, P.R. Owens, and N. Curi. 2020. Soil quality indices based on long-term conservation cropping systems management. Agrosystems, Geosciences & Environment. 3:e20036. doi.org/10.1002/agg2.20036

Anderson, K., P.A. Moore, Jr., and J. Martin, and A.J. Ashworth. 2020. Effect of a new manure amendment on ammonia emissions from poultry litter. Atmosphere. 11, 225. doi:10.3390/atmos11030257

Kharel, T.P., A.J. Ashworth, A. Shew, M. Popp, and P.R. Owens. 2020. Tractor guidance improves production efficiency by reducing overlaps and gaps. Agricultural & Environmental Letters. 5:e20012. doi.org/10.1002/ael2.20012

Kharel, T.P., A.J. Ashworth, P.R. Owens, and M. Buser. 2020. Spatially and temporally disparate data in systems agriculture: issues and prospective solutions. Agronomy Journal. 112:4498–4510. doi.org/10.1002/agj2.20285

Amorim, H.C.S., A.J. Ashworth, P.A. Moore, Jr., B.J. Wienhold, M.S. Savin, P.R. Owens, S. Jagadamma; T. Carvalho, and S. Xu. 2020. Soil quality indices following long-term conservation pasture management practices. Agriculture, Ecosystems and Environment. 301.

107060. doi.org/10.1016/j.agee.2020.107060

Kharel, T.P., P.R. Owens, and A.J. Ashworth. 2020. Tractor path overlap is influenced by field shape and terrain attributes. Agricultural & Environmental Letters. 5:e20027. doi.org/10.1002/ael2.20027

Xu, S., S. Jagadamma, A.J. Ashworth, S. Surendra, P.R. Owens, and P.A. Moore, Jr. 2020. Long-term effects of pasture management and fenced riparian buffers on soil organic carbon content and aggregation. Geoderma. 382, 114666, doi.org/10.1016/j.geoderma.2020.114666.

Ashworth, A.J., K. V. Knapp, F.L. Allen, and A.M. Saxton. 2020. Comparison of discriminatory effects of corn yield test locations based on their genetic variation expression among hybrids. Crop Sci. 60: 3166–3174. doi.org/10.1002/csc2.20298

Gelley, C.H., A.J. Ashworth, P.D. Keyser, R. Nave-Oakes, and J. Reinhart. 2020. Water-use efficiency of forage crops in the Southeastern United States. Agronomy. 10: 9, 1377; doi.org/10.3390/agronomy10091377

Yang, Y., A.J. Ashworth, J. DeBruyn, L.M. Durso, M. Savin, K. Cook, P.A. Moore, Jr., and P.R. Owens. 2020. Antimicrobial resistant gene prevalence in soils due to animal manure deposition and long-term pasture management. PeerJ 8:e10258. doi.org/10.7717/peerj.10258

Amorim, H.C.S., A.J. Ashworth, K.R. Brye, B.J. Wienhold, M.C. Savin, P.R. Owens, and S.H. G. Silva. 2021. Soil quality indices as affected by long-term burning, irrigation, tillage, and fertility management. Soil Science Society of America J. 85:379–395. doi:10.1002/saj2.20188

Ashworth, A.J., P.A. Moore, D.H. Pote, P.R. Owens, J. Martin, and K. Anderson. 2021. Conservation management practices reduce non-point source pollution from grazed pastures. Heliyon. 7, e06238. doi.org/10.1016/j.heliyon.2021.e06238.

Gurmessa, B., A.J. Ashworth, Y. Yang, K. Adhikari, M. Savin, P.R. Owens, T. Sauer, E.F. Pedretti, S. Cocco, and G. Corti. 2021. Soil bacterial diversity based on management and topography in a silvopastoral system. Applied Soil Ecology. 163, 103918. doi.org/10.1016/j.apsoil.2021.103918

Niyigena, V., A.J. Ashworth, C. Nieman, M. Achara, K.P. Coffey, D. Philipp, L. Meadors, and T.J. Sauer. 2021. Factors affecting sugar accumulation and fluxes in warm- and cool-season forages grown in a silvopastoral system. Agronomy. 11, 354. doi.org/10.3390/agronomy11020354

Gurmessa, B., A.J. Ashworth, Y. Yang, M. Savin, P.A. Moore Jr., S. Ricke, G. Corti. E.F. Pedretti, and S. Cocco. 2021.Variations in bacterial community structure and antimicrobial resistance gene abundance in cattle manure and poultry litter. Environmental Research. 97, 111011. doi.org/10.1016/j.envres.2021.111011

Acharya, M., A.J. Ashworth, Y. Yang, J.M. Burke, J.A. Lee, and R. Sharma-Acharya. 2021. Soil microbial diversity in organic and non-organic pasture systems. PeerJ 9:e11184. doi.org/10.7717/peerj.11184

Zhou, V., J.A. Larson, V.R. Sykes, A.J. Ashworth, and F.L. Allen. 2021. Crop rotation, cover crop, and poultry litter effects on no-tillage cotton profitability. Agronomy Journal. 113: 2648– 2663. doi.org/10.1002/agj2.20661

Yang, Y., A.J. Ashworth, L.M. Durso, M. Savin, J. DeBruyn, K. Cook, P.A. Moore, Jr., and P.R. Owens. 2021. Do long-term conservation pasture management practices influence microbial diversity and antimicrobial resistant genes in runoff? Frontiers in Microbiology. 12, 617066. doi.org/10.3389/fmicb.2021.617066

Popp, M.P., A.J. Ashworth, and C.P. West. 2021. Simulating the feasibility of dual use switchgrass. Energies. 14, 2422. doi.org/10.3390/en14092422

Anderson, K., P.A. Moore, Jr., J. Martin, and A.J. Ashworth. 2021. Evaluation of a novel poultry litter amendment on greenhouse gas emissions. Atmosphere. 12, 563. doi.org/10.3390/atmos12050563

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**Kentucky Report 2020-2021**

**University of Kentucky**

**1. Impact Nugget**

The forage group at the University of Kentucky (UK) conducts research on how symbioses between forage species and microbes affects forage production, nutritive value, secondary plant metabolites, invasive potential, resilience to climate change and mitigation potential. The forage extension program at UK is good-sized, 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 University of Kentucky transformed our western Kentucky farm and field station (UKREC), with a new building containing offices, meeting spaces, teaching facilities, and labs, built by generous support from the Kentucky Agricultural Development Board ($15M) and additional philanthropic gifts. The new building is called the Grain & Forage Center of Excellence, is located in Princeton, KY, and houses one UK Forage Extension Specialist – Dr. Chris Teutsch.

The USDA-ARS-FAPRU group has received Federal money for a new building on the UK campus, which will house most of the UK forage group and other UK faculty. A location on the UK campus in Lexington has been identified, and site planning and building design processes have begun. The building is currently anticipated to open in Spring 2026.

**3.** **Unique Project-Related Findings**

Soil nitrogen (N) availability is critical for grassland functioning. However, human activities

have increased the supply of biologically limiting nutrients and changed the density and identity of mammalian herbivores. These anthropogenic changes may alter net soil N mineralization (soil net Nmin), that is, the net balance between N mineralization and immobilization, which could severely impact grassland structure and functioning. Yet, to date, little is known about how fertilization and herbivore removal individually, or jointly, affect soil net Nmin across a wide range of grasslands that vary in soil and climatic properties. We collected data from 22 grasslands on five continents, all part of a globally replicated experiment, to assess how fertilization and herbivore removal affected potential (laboratory-based) and realized (field-based) soil net Nmin. Herbivore removal in the absence of fertilization did not alter potential and realized soil net Nmin. However, fertilization alone and in combination with herbivore removal consistently increased potential soil net Nmin. Realized soil net Nmin, in contrast, significantly decreased in fertilized plots where herbivores were removed. Treatment effects on potential and realized soil net Nmin were contingent on site-specific soil and climatic properties. Fertilization effects on potential soil net Nmin were larger at sites with higher mean annual precipitation (MAP) and temperature of the wettest quarter (T.q.wet). Reciprocally, realized soil net Nmin declined most strongly with fertilization and herbivore removal at sites with lower MAP and higher T.q.wet. In summary, our findings show that anthropogenic nutrient enrichment, herbivore exclusion and alterations in future climatic conditions can negatively impact soil net Nmin across global grasslands under realistic field conditions. This is an important context-dependent knowledge for grassland management worldwide.

**4.** **Accomplishment Summaries**

During 2020, faculty from University of Kentucky published data from forage and alfalfa variety trials, a number of scientific studies, and trained numerous undergraduate and graduate students. Outreach activities were dramatically impacted by the COVID-19 pandemic and shifted to primarily online, though some traditional activities continued in a reduced capacity or altered fashion (e.g., farm visits, interactions with producer and commodity groups, farm visits, etc.). We collected data on the third version of our climate change study, focused on red clover and alfalfa, and we continued work in collaboration with USDA-ARS-FAPRU evaluating the effects of biochanin A (an isoflavone produced by red clover) supplementation on ruminant microbes and resulting N use efficiency and N excreta to the environment, as well as excreta effects on greenhouse gas emissions from soils.

**5. Impact Statements**

*"Increasing effects of chronic nutrient enrichment on plant diversity loss and ecosystem productivity over time" - Seabloom et al. 2020. Ecology.*

*Issue:* Human activities are enriching many of Earth's ecosystems with biologically limiting mineral nutrients such as nitrogen (N) and phosphorus (P). In grasslands, this enrichment generally reduces plant diversity and increases productivity. The widely demonstrated positive effect of diversity on productivity suggests a potential negative feedback, whereby nutrient-induced declines in diversity reduce the initial gains in productivity arising from nutrient enrichment. In addition, plant productivity and diversity can be inhibited by accumulations of dead biomass, which may be altered by nutrient enrichment. Over longer time frames, nutrient addition may increase soil fertility by increasing soil organic matter and nutrient pools.

*Action:* We examined the effects of 5–11 yr of nutrient addition at 47 grasslands in 12 countries. Nutrient enrichment increased aboveground live biomass and reduced plant diversity at nearly all sites, and these effects became stronger over time. We did not find evidence that nutrient-induced losses of diversity reduced the positive effects of nutrients on biomass; however, nutrient effects on live biomass increased more slowly at sites where litter was also increasing, regardless of plant diversity.

*Impact:* This work suggests that short-term experiments may underestimate the long-term nutrient enrichment effects on global grassland ecosystems.

*“Nutrient availability controls the impact of mammalian herbivores on soil carbon and nitrogen pools in grasslands" - Sitters et al. 2020. Global Change Biology*

*Issue:* Grasslands are subject to considerable alteration due to human activities globally,

including widespread changes in populations and composition of large mammalian

herbivores and elevated supply of nutrients. Grassland soils remain important reservoirs

of carbon (C) and nitrogen (N). Herbivores may affect both C and N pools and

these changes likely interact with increases in soil nutrient availability. Given the scale

of grassland soil fluxes, such changes can have striking consequences for atmospheric

C concentrations and the climate.

*Action:* We used the Nutrient Network experiment to examine the responses of soil C and N pools to mammalian herbivore exclusion across 22 grasslands, under ambient and elevated nutrient availabilities (fertilized with NPK + micronutrients). We show that the impact of herbivore exclusion on soil C and N pools depends on fertilization. Under ambient nutrient conditions, we observed no effect of herbivore exclusion, but under elevated nutrient supply, pools are smaller upon herbivore exclusion. The highest mean soil C and N pools were found in grazed and fertilized plots. The decrease in soil C and N upon herbivore exclusion in combination with fertilization correlated with a decrease in aboveground plant biomass and microbial activity, indicating a reduced storage of organic matter and microbial residues as soil C and N. The response of soil C and N pools to herbivore exclusion was contingent on temperature – herbivores likely cause losses of C and N in colder sites and increases in warmer sites. Additionally, grasslands that contain mammalian herbivores have the potential to sequester more N under increased temperature variability and nutrient enrichment than ungrazed grasslands.

*Impact:* Our study highlights the importance of conserving mammalian herbivore populations in grasslands worldwide. We need to incorporate local-scale herbivory, and its interaction with nutrient enrichment and climate, within global-scale models to better predict land–atmosphere interactions under future climate change.

**6. Published Written Works**

***Refereed Journal Articles***

* Friesen, G.M.A., **S.R. Smith**, D.J. Cattani, and A.T. Phan. **2020**. Characterizing genetically diverse blue grama [Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths] seed sources. Can. J. Botany 98:11. https://doi.org/10.1139/cjb-2020-0029
* Gilbert, B., A.S. MacDougall, T. Kadoya, M. Akasaka, J.R. Bennett, E.M. Lind, H. Flores-Moreno, J. Firn, Y. Hautier, E.T. Borer, E.W. Seabloom, P.B. Adler, E.E. Cleland, J.B. Grace, W.S. Harpole, E.H. Esch, J.L. Moore, J. Knops, **R.L. McCulley**, B. Mortensen, J. Bakker, and P.A. Fay. Climate and local environment structure asynchrony and the stability of primary production in grasslands. **2020**. Global Ecology and Biogeography 29(7):1177-1188. doi: 10.1111/geb.13094.
* Hautier, Y., P. Zhang, M. Loreau, K. Wilcox, E. Seabloom, E. Borer, J. Byrnes, S. Koerner, K. Komatsu, J. Lefcheck, A. Hector, P. Adler, J. Alberti, C. Arnillas, J. Bakker, L. Brudvig, M. Bugalho, M. Cadotte, M. Caldeira, O. Carroll, M. Crawley, S. Collins, P. Daleo, L. Dee, N. Eisenhauer, A. Eskelinen, P. Fay, B. Gilbert, A. Hansart, F. Isbell, J. Knops, A. MacDougall, **R.L. McCulley**, J. Moore, J. Morgan, A. Mori, P. Peri, E. Pos, S. Power, J. Price, P. Reich, A. Risch, C. Roscher, M. Sankaran, M. Schueltz, M. Smith, C. Stevens, P. Tognetti, R. Virtanen, G. Wardle, P. Wilfhart, and S. Wang. **2020**. General destabilizing effects of eutrophication on grassland productivity at multiple spatial scales. Nature Communications 11:5375. doi: 10.1038/s41467-020-19252-4
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* Kramer, K.J., I.A. Kagan, L.M. Lawrence, B. M. Goff, and **S.R. Smith**. **2020**. Water-soluble carbohydrates of cool-season grasses: prediction of concentrations by near-infrared reﬂectance spectroscopy and evaluation of effects of genetics, management, and environment. J. of Equine Vet. Science 90: 103014. https://doi.org/10.1016/j.jevs.2020.103014
* Meyer, Susan, Margaret H. MacDonald, Nathan D. Reetz, Mihail R. Kantor, Lynn Carta, Zafar Ahmad Handoo, Mary J. Camp, and **Tim D. Phillips**. **2020**. Chia: Host status for Meloidogyne incognita and activity of plant extracts. Plant Disease. doi.org/10.1094/PDIS-10-19-2171-RE
* Risch, A., S. Zimmermann, B. Moser, M. Schuetz, F. Hagedorn, J. Firn, P. Fay, P. Adler, L. Biederman, J. Blair, E. Borer, A. Broadbent, C. Brown, M. Cadotte, M. Caldeira, K. Davies, A. di Virgilio, N. Eisenhauer, A. Eskelinen, J. Knops, A. MacDougall, **R.L. McCulley**, B. Melbourne, J. Moore, S. Power, S. Prober, E. Seabloom, J. Siebert, M. Silveira, K. Speziale, C. Stevens, P. Tognetti, R. Virtanen, L. Yahdjian, and R. Ochoa-Hueso. **2020**. Global impacts of fertilization and herbivore removal on soil net nitrogen mineralization are modulated by local climate and soil properties. Global Change Biology 26(12): 7173-7185. doi: 10.1111/gcb.15308
* Ochoa-Hueso, R., E.T. Borer, E.W. Seabloom, S.E. Hobbie, A.C. Risch, S.L. Collins, J. Alberti, H.A. Bahamonde, C.S. Brown, M.C. Caldeira, P. Daleo, C.R. Dickman, A. Ebeling, N. Eisenhauer, E.H. Esch, A. Eskelinen, V. Fernandez, S. Gusewell, B. Gutierrez-Larruga, K. Hofmockel, R. Laungani, E. Lind, A. Lopez, **R.L. McCulley**, J.L. Moore, P.L. Peri, S.A. Power, J.N. Price, S.M. Prober, C. Roscher, J.M. Sarneel, M. Schutz, J. Siebert, R.J. Standish, S. Velasco Ayuso, R. Virtanen, G.M. Wardle, G. Wiehl, L. Yahdjian, and T. Zamin. **2020**. Microbial processing of plant remains is co-limited by multiple nutrients in global grasslands. Global Change Biology 26(8):4572-4582. doi: 10.1111/gcb.15146.
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* Serson, W., P. Armstrong, E. Maghirang, A. AL-Bakri, **T.D. Phillips**, M. AL-Amery, K. Su, and D.F. Hildebrand. **2020**. Development of Whole and Ground Seed Near-Infrared Spectroscopy Calibrations for Oil, Protein, Moisture, and Fatty Acids in Salvia hispanica, JAOCS, Journal of the American Oil Chemists' Society, 7(1), 3-13. doi: 10.1002/aocs.12300
* Sitters, J., E.R.J. Wubs, E.S. Bakker, T.W. Crowther, P.B. Adler, S. Bagchi, J.D. Bakker, L. Biederman, E.T. Borer, E.E. Cleland, N. Eisenhauer, J. Firn, L. Gherardi, N. Hagenah, Y. Hautier, S.E. Hobbie, J.M.H. Knops, A.S. MacDougall, **R.L. McCulley**, J.L. Moore, B. Mortensen, P.L. Peri, S.M. Prober, C. Riggs, A.C. Risch, M. Schutz, E.W. Seabloom, J. Siebert, C.J. Stevens, and G.F. Veen. **2020**. Nutrient availability controls the impact of mammalian herbivores on soil carbon and nitrogen pools in grasslands. Global Change Biology 26(4):2060-2071. doi: 10.1111/gcb.15023.
* Stanton, V.L., E.R. Haramoto, and **T. Phillips**.  **2020**. Biomass potential of drill interseeded cover crops in corn in Kentucky. Agronomy Journal  https://doi.org/10.1002/agj2.20609
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* Tao, B., Y.J. Yang, J. Yang, **R. Smith**, J. Fox, A. Ruane, J.Z. Liu, and W. Ren. **2020**. Recent shrinkage and fragmentation of bluegrass landscape induced by crop expansion in Kentucky. Remote Sensing: 12(11), https://doi.org/10.3390/rs12111815

***Peer-Reviewed Book Chapters***

Aiken, G. E., **J.C. Henning**, E. Rayburn. **2020**. Ch. 9: Management strategies for pastures, beef cattle, and marketing of stocker-feeder calves in the Upper South: The I-64 Corridor. In Management Strategies for Sustainable Cattle Production in Southern Pastures, eds. M. Roquette, Jr and G.E. Aiken. pp. 227-264. doi: 10.1016/B978-0-12-814474-9.00009-8

***Proceedings Publications***

Mercier, K., **C. Teutsch**, S.R. Smith, E.L. Ritchey, K. Burdine, and E. Vanzant. **2020**. Applying N to Legume-Containing Summer Annual Forage Mixtures. Proceedings of the 50th Annual North Central Extension-Industry Soil Fertility Conference, Des Moines, IA.

***Extension Publications***

Halich, G., J. Lehmkuhler, L. Meyer, G. Rentfrow, and R. Smith. **2020**. Producer's Guide to Pasture-Based Beef Finishing. ID-224.

Mercier, K. and C. Teutsch. **2020**. Strategies for Reclaiming Hay Feeding Areas. AGR-255.

Ritchey, E. and C. Teutsch. **2020**. Soil Sampling Pastures and Hayfields. AGR-252.

Buckman, J. and C. Teutsch. **2020**. Grain Drill Calibration: Don't Make a Mistake--CALIBRATE! AGR-254.

Bush, J., J. Henning, T. Keene, and C. Teutsch. **2020**. Hay Sampling: Strategies for Getting a Good Sample. AGR-257.

Knott, C., C. Teutsch, and K. VanValin. **2020**. Considerations for Utilizing Frozen Small Grains for Forage. IP-262.

Haramoto, E., J. Henning, C. Knott, C. Lee, and R. Smith. **2020**. Grain, Forage, and Cover Crop Guide. AGR-18.

Call, D., J. Grove, A.D. Karanthanasis, C. Matocha, and L. Murdock. **2020**. Remediation of the Fragipan using Annual Ryegrass. AGR-250.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2020**. 2020 Timothy and Kentucky Bluegrass Report. PR-785.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2020**. 2020 Long-Term Summary of Kentucky Forage Variety Trials. PR-792.

Bruening, B., J. Henning, G. Olson, R. Smith, and C. Teutsch. **2020**. 2020 Annual Grass Report: Warm Season and Cool Season (Cereals). PR-791.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2020**. 2020 Cool-Season Grass Grazing Tolerance Report. PR-789.

Henning, J., L. Lawrence, G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2020**. 2020 Cool-Season Grass Horse Grazing Tolerance Report. PR-790.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2020**. Alfalfa Grazing Tolerance Report. PR-787.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2020**. 2020 Red and White Clover Grazing Tolerance Report. PR-788.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2020**. 2020 Orchardgrass Report. PR-783.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2020**. 2020 Annual and Perennial Ryegrass and Festulolium Report. PR-786.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2020**. 2020 Alfalfa Report. PR-781.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2020**. 2020 Red and White Clover Report. PR-782.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2020**. 2020 Tall Fescue and Bromegrass Report. PR-784.

**7. Scientific and Outreach Oral Presentations**

None in 2020 due to COVID.

**8. Collaborative Grants**

McCulley, R.L. (PI). “Utilizing grass-endophyte technology to improve pasture soil health and resilience to climate change stressors and soil health.” ***NIFA-AFRI-Foundational – Agricultural Production Systems***. 2017-2022. **$500,000**

McCulley, R.L. (PI). “Determining red clover drought resistance under abiotic stress and exploring effects of clover-produced isoflavones on animal nitrogen excreta, soil-to-atmosphere trace gas production, and soil microbial communities.” ***USDA-FAPRU-Specific Cooperative Agreement***. 2018 – 2023. **$119,942**

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**

**9.** **Graduate Students**

**Jordyn Bush**, MS in Integrated Plant & Soil Sciences, expected graduation **2023**, title - TBD.

**Echo Gotsick**, MS in Integrated Plant & Soil Sciences, expected graduation **2023**, title - TBD.

**Alayna Jacobs**, PhD in Integrated Plant & Soil Sciences, expected graduation **2022**, title – TBD.

**Kelly Mercier**, PhD in Integrated Plant & Soil Sciences, graduated **2021**, "Incorporation of summer annual mixtures into grazing systems in Kentucky"

**Contact:**

R.L. McCulley, Professor & Chair

Department of Plant & Soil Sciences, University of Kentucky

859-257-6388 / [rebecca.mcculley@uky.edu](mailto:rebecca.mcculley@uky.edu)

**Maryland Report 2020-2021**

**University of Maryland**

1. Impact Nugget: Our current research emphasizes the spatial and temporal movement of insect pests and natural enemies in the farmscape, and their influence on ecosystem services within forage systems, as well as the development of sustainable practices for forage/livestock systems.

2. New Facilities and Equipment: None

3. Unique Project Related Findings:

We discovered diverse, beneficial taxa of invertebrates associated with agricultural drainage ditches adjacent to crops.

Pasture-raised lambs that received daily energy supplementation in the form of whole barley had higher average daily gain and body condition score compared to pasture-raised lambs that did not receive daily energy supplementation; however, the value of the additional gain would not have covered the cost of feed.

Increasing the rate of nitrogen fertilization had no effect on triticale yield, neutral detergent fiber, or total digestible nutrients, but increased forage crude protein concentrations in a linear fashion.

4. Accomplishment Summaries

Dragonflies and damselflies (Odonata) as beneficial predators in alfalfa (*Medicago sativa*).

Margaret E. Hartman and William O. Lamp.

Dragonflies and damselflies are opportunistic predators as adults. However, the potential for adult dragonflies as biological control agents in alfalfa (*Medicago sativa*) has been understudied. The primary goal of this study is to compare richness and abundance of assemblages of adult species of dragonflies and damselflies among farms and crops. Visual encounter surveys were conducted at three University of Maryland farms during the 2020 and 2021 field seasons. We hope to highlight the importance of adult dragonflies as generalist natural enemies in alfalfa by first determining their richness and abundance in agroecosystems. Odonata provide humans with ecosystem services in several ways, with one primary contribution being their ability to eat large quantities of arthropods often considered pest species. Predatory insects used as biological control in agriculture are an alternative to chemical pesticides and can indirectly improve soil and water quality by reducing chemical inputs into the environment. The primary goal of this study is to compare richness and abundance of assemblages of adult species of dragonflies and damselflies among farms and crops. Thirty-minute visual encounter surveys (VES) of adult odonates in alfalfa were conducted at three University of Maryland farms in central and western Maryland during the summer 2020 and summer 2021 field seasons. During the VES, the number of novel dragonfly and damselfly encounters were recorded. Crop height, cloud cover, temperature, wind speed, time, behavior at time of sighting and sex were recorded. The behavior of the dragonfly can be described as flying, perching, foraging, aggression or tandem flying. A total of 16 species of Odonata were identified in alfalfa during the 2020 and 2021 summer seasons. Of these, 14 were Anisoptera and 2 were Zygoptera. The family Libellulidae comprised 11 of the total 16 species in alfalfa. The most abundant species in alfalfa between both field seasons were all libellulids and included *Tramea lacerata*, *Libellula luctosa* and *Plathemis lydia*. During sampling events, anywhere from 0 to 15 odonates were detected with an average abundance of 3. This was significantly less than average abundance in both corn and soy fields (P < 0.0001). Perching and flying behavior varied among species, and thus foraging tactics were varied. *Tramea lacerata* were observed exclusively foraging about ten feet above the crop canopy, eating on the wing and perching on tall structures. They were never observed perched on the ground. Conversely, *Plathemis lydia* were observed flying low to the ground and directly above the crop canopy. *P. lydia* were observed perching over 70% of the time, but foraging behavior was rarely observed. Species in alfalfa primarily flew low in the vegetation and favored high perches, such as sticky trap rods. Additionally, many odonate observations were made along the edge of the alfalfa, corn and soy, where plant structure, height and complexity changed dramatically. The height of the alfalfa was noted during odonate visual encounter surveys and it varied from 3 cm to 58 cm throughout the growing season. There was no clear trend between odonate abundance and alfalfa canopy height, but several other variables need to be investigated such as temperature and sex. This study provides a first examination of the importance of adult dragonflies as generalist predators of agricultural pests. We can begin to inform farmers of the importance of dragonflies as natural enemies, and identify ways to encourage dragonfly communities in agroecosystems to enhance conservation biological control and thus lessen reliance on pesticides.

Colonization and development of natural enemies in alfalfa cultivars neighboring soybean: A landscape complexity approach to enhance biological control. Darsy Smith and William O. Lamp.

Conservation biological control (CBC) is the implementation of practices to facilitate the reproduction and survival of natural enemies in a cropping system. Different than other types of biological control, CBC seeks to enhance natural enemy populations by managing habitats. The ecosystems provided by natural enemies in these habitats include suppression of pest populations, pollination, and prevention of secondary pest outbreaks. Despite the diversity of natural enemies in cropping system may be well documented little is known about best management practices to enhance their reproduction. A common practice in cropping systems is the selection of the cultivar which offer options to control potato leafhopper (PLH: *Empoasca fabae*: Hemiptera: Cicadellidae). It is unknow if alfalfa PLH resistant cultivar enhance natural enemy reproduction when comparing to PLH susceptible cultivar. To test this question our objectives are to compare the colonization, reproduction, and development time of lady beetles in two alfalfa cultivars and determine the survivorship of lady beetles after harvest. We started conducting a randomized block design experiment at the Western Maryland Research and Education Center in Keedysville, Maryland mid-April 2021. Each block includes: 1) PLH resistant alfalfa cultivar, 2) PLH susceptible alfalfa cultivar, and 3) soybean. The samples were collected on a weekly basis to measure absolute densities from sweep samples, sticky traps, and foliar samples. A total of 7 species of Coccinellidae were collected from both alfalfa cultivars and 3 of them are currently in pending for id confirmation. The Simpson’s Index of Diversity for sweep samples from PLH resistant cultivar was 0.21 while for PLH susceptible cultivar was 0.71. The predominant species in both cultivars was *Coccinella septempunctata*. From the almost three months of sampling in two occasions 1 larva of coccinellid was observed and 2 adults of *C. septempunctata* We observed no survival of lady beetles after the harvest on May 12 and the harvest on June 16. The diversity of coccinellids in cropping systems may be potentially increased by selecting the PLH susceptible cultivar. Overall, these preliminary results suggest that the selection of the cultivar may play a role in coccinellids success in cropping systems despite their low abundance comparing to alfalfa pest. Further research is needed to understand how the selection of the cultivar impacts lady beetle development.

Diversity of natural enemy assemblages in drainage ditches and adjacent crops. Alireza Shokoohi and W. Lamp.

Agricultural drainage ditches, which are common structures on farms along Maryland’s Eastern Shore, are typically using to provide hydrological control for croplands located above high-water tables. Recently, drainage ditches have begun to receive attention as potential sources of beneficial arthropods for adjacent croplands, such as natural enemies of agricultural pests. Spiders, the most abundant generalist predators in agroecosystems, have been previously been supported as abundant and diverse natural enemies living in drainage ditches in Maryland. This report focuses on spiders, but additional sampling is underway for carabid beetles, parasitic hymenopterans, and other generalist predators. To better understand to what extent spiders in drainage ditches colonize crops growing in adjacent croplands, we investigated the following research objectives: (1) to assess how spider assemblages in drainage ditches and their neighboring croplands change throughout the soybean growing season, (2) to determine what spiders colonize croplands from drainage ditches, and (3) to identify what environmental conditions influence spider assemblages and colonization between drainage ditches and croplands. We implemented an experimental design during the 2018 and 2019 soybean growing seasons on a private organic farm, where spiders were collected from drainage ditches and their adjacent soybean fields at specific distances leading into the field from the ditch via foliar sweep netting and pitfall trapping. During the preliminary 2018 growing season, one drainage ditch on our organic farm was selected to collect spiders from to test our experimental design. During the next soybean growing season in 2019, this methodology was expanded upon to include three drainage ditches and assess environmental data such as prey abundance, ground-level temperature and humidity, and plant assemblage metrics. We found that drainage ditches possess spider species that migrate to soybean fields as the growing season progresses, as soybean fields begin to offer comparable prey availability as drainage ditches later in the growing season. Spider diversity and abundance in drainage ditches was significantly higher than in-field diversity and abundance early in the growing season (p<0.05). As the soybean growing season progressed, spider assemblages in ditches and soybean fields became more similar in diversity and abundance. Linear regression analysis comparing prey abundance and spider abundance across drainage ditches and their adjacent croplands found that prey abundance has a positive significant association with spider abundance in these habitats. Drainage ditches were found to simplify in their plant diversity as the growing season progresses, and thus provide less prey abundance for spiders over time, while soybean fields increased in prey abundance as they grew.

A Forage-Based Educational Needs Assessment for Livestock and Forage Producers in Maryland.

Amanda Grev and Sarah Potts

The objective of this project was to collect and formally document information on the educational needs, preferences, and challenges for livestock and forage producers in Maryland. To accomplish this, a needs assessment survey was conducted online during April/May 2020. The survey was open to all livestock and forage producers and consisted of 36 questions designed to collect information on educational preferences, production and management practices, and forage-related challenges/successes. The survey was completed by 159 respondents spanning the dairy, beef, small ruminant, equine, and forage production industries. The majority of respondents were male (59%), were 35 to 64 years old (70%), and had been involved in the industry for more than 11 years (61%). Rank-type questions were analyzed on a scale of 1 to 4, with 1 indicating no value/interest and 4 indicating a high value/interest. Private consultants (3.42) and regional sales representatives (3.09) received the highest rating as sources for forage-related information. The most preferred formats for receiving information included internet webpages (2.87), half-day sessions (2.85), and newsletters (2.83). Respondents showed the greatest interest in education on extending the grazing season (3.36), weed control (3.36), and improving soil organic matter (3.30). When asked to identify limitations to improving forage production, a lack of time/labor (2.44), high fertilizer costs (2.27), and dependence on hay (2.25) were listed as most limiting. The results of this assessment will be used to help Extension educators generate more effective forage-related educational programming to better meet the needs of the agricultural community in Maryland.

Effect of Energy Supplementation on Growth, Health, and Carcass Traits of Pasture-Raised Lambs.

Amanda Grev, Susan Schoenian, Jeff Semler, and Dahlia O’Brien

Energy is often the most limiting nutrient in pasture diets. The effect of energy supplementation on the growth, health, and carcass traits of pasture-raised lambs was investigated. Seventy-nine Katahdin ram lambs were delivered to the Western Maryland Research & Education Center on June 15, 2020. After an 11-d acclimation period, lambs were allocated to two treatment groups based on age, weight, birth type, and FEC. Lambs in the PASTURE group (n=40) rotationally grazed 2 ha of high quality, mixed pasture for 102 d. Lambs in the SUPPL group (n=39) grazed similar pastures and were hand-fed a daily energy supplement (450 g of whole barley). The groups were handled bi-weekly to determine body weights, FAMACHA©, BCS, and dag scores. Individual fecal samples were collected upon arrival and at two additional time points. Lambs were ultrasound scanned on Sept 25 to determine carcass traits. Data was analyzed using the MIXED procedure of SAS, with statistical significance set at *P*≤ 0.05. ADG varied considerably among weigh periods. Standard deviations were typically quite large, indicating wide variation in individual performance. Overall, the SUPPL lambs had higher ADG (p< 0.01), more backfat (p< 0.03), and higher BCS (p< 0.01) than the PASTURE lambs. There were no statistical differences in starting weight, ending weight, and loin depth. While internal parasites were not a problem during the study (only one lamb had a FAMACHA© score >4), PASTURE lambs had lower FEC (p< 0.05) on August 17 (240 ± 81 vs. 468 ± 80 epg). The value of additional gain (0.9 kg) would not have covered the cost of feed; however, four lambs were removed from the PASTURE group (due to death or failure to thrive) whereas only two lambs were removed from the SUPPL group. The study is currently being repeated in 2021 with similar lambs and protocol.

Effects of Nitrogen and Sulfur Fertility on Triticale Forage Protein Concentrations and Dairy Cow Performance. Amanda Grev, Sarah Potts, and Jeff Semler

Winter forages like triticale can provide environmental benefits through increased nutrient retention and soil erosion control while also producing a high-yielding and high quality forage crop for livestock. Triticale can also serve as a good source of protein, potentially making it a more economical alternative to other feed ingredients such as soybean meal and allowing livestock producers to meet the nutritional needs of their animals while reducing overall feed expenses. The objectives of this study are to compare varying nitrogen fertility rates with and without sulfur on triticale forage to determine if using a higher fertilization rate will the increase the value of the forage through increased protein concentrations, as well as the resulting implications of incorporating that forage into the ration for lactating dairy cattle. The research will be completed in three main parts, including an initial field trial to assess soil nutrient status, forage quality, and forage yield under varying nitrogen and sulfur fertility treatments, followed by a feeding study to assess dairy cow production and performance when fed the resulting forage, and then finally an economic analysis to assess the effectiveness of the system. In the fall of 2020, triticale forage plots were established at two locations in Maryland. Fertility treatments included the following: CON (0 lb N, 0 lb S), SUL (0 lb N, 15 lb S), NLOW (50 lb N, 0 lb S), NSLOW (50 lb N, 15 lb S), NMED (100 lb N, 0 lb S), NSMED (100 lb N, 15 lb S), NHIGH (150 lb N, 0 lb S), and NSHIGH (150 lb N, 15 lb S). Treatments were applied to the established triticale plots in a randomized complete block design with 4 replicates at each location in March 2021. Plots were mechanically harvested in April 2021 and weighed to determine yield, and forage samples were collected to determine forage nutritive value. At both locations, yields for the fertility treatments were similar but were increased compared to the CON and SUL control treatments. Crude protein concentrations were lowest for the CON and SUL treatments and increased with increasing fertility, with the NHIGH and NSHIGH treatments containing the greatest amount of protein. Neutral detergent fiber and total digestible nutrients did not differ between treatments. These initial results indicate that fertility can influence forage protein concentrations. The feeding study portion of this project will begin in fall 2021, and the study will be repeated in 2022.

5. Impact Statements

6. Published Written Works

Avanesyan, A., and W. Lamp. 2020. Use of molecular gut content analysis to decipher the range of food plants of the invasive spotted lanternfly, *Lycorma delicatula*. Insects 11, 215.

Avanesyan, A., H. Sutton, and W. Lamp. 2021. Choosing an effective PCR-based approach for diet analysis of insect herbivores: a systematic review. Journal of Economic Entomology doi: 10.1093/jee/toab057.

Avanesyan, A., N. Illahi, and W. Lamp. 2021. Detecting ingested host plant DNA in potato leafhopper, *Empoasca fabae*: potential use of molecular markers for gut content analysis. Journal of Economic Entomology 114: 472-475. doi: 10.1093/jee/toaa247

Eckert, R., H. Halvorson, K. Kuehn, and W. Lamp. 2020. Macroinvertebrate community patterns in relation to leaf-associated periphyton under contrasting light and nutrient conditions in headwater streams. Freshwater Biology 65: 1270-1287. DOI: 10.1111/fwb.13473

Eckert, R., W. Lamp, and G. Marbach-Ad. 2021. Jigsaw dissection activity enhances student ability to relate morphology and ecology in aquatic insects. Journal of Biological Education (in press)

Thompson, M., and W. Lamp. 2021. Herbivory enhances legume-rhizobia symbioses function, increasing aboveground allocation of biologically fixed nitrogen, but only in soils without additional nitrate. Plant Soil <https://doi.org/10.1007/s11104-021-04999-6>.

Wallau, M., A. Lazur, A. Grev, S. Rondon, and J. Robinson. 2021. Organizing virtual field events: opportunities, strategies, and lessons from across the country. Journal of Extension. *Submitted April 2021*.

Wilson-Ounekeo, R. and W. Lamp. 2020. Perceptions and responses of residents to the nuisance black fly *Simulium jenningsi* (Diptera: Simuliidae) in the mid-Atlantic United States. Journal of Medical Entomology 57: 1872–1881, [DOI: /10.1093/jme/tjaa129](https://doi.org/10.1093/jme/tjaa129)

Wilson-Ounekeo, R., and W. Lamp. 2021. Environmental and spatial predictors of the distribution patterns of the host-seeking black fly, *Simulium jenningsi*. Environmental Entomology (in press)

Yurchak, V., A. Leslie, G.P. Dively, W.O. Lamp, and C.R.R. Hooks. 2021. Degradation of transgenic *Bacillus thuringiensis* proteins in corn residue to post-harvest management practices. Transgenic Research <https://doi.org/10.1007/s11248-021-00273-8>

7. Scientific and Outreach Presentations

*Abstracts , symposium and conference presentations*

Grev, A., S. Schoenian, J. Semler, and D. O'Brien. 2021. Effect of energy supplementation on growth, health, and carcass traits of pasture-raised lambs. Journal of Animal Science.

Grev, A.M. and S.B. Potts. 2021. A forage-based educational needs assessment for equine operations in Maryland. Journal of Equine Veterinary Science. 100: 103588.

Perdue, M.A., J.R. Moyle, A.M. Grev, S.B. Potts, J.W. Semler, E. Zobel, and R.G. Slattery. 2021. Small farm programming during a pandemic. In Proceedings: National Association of County Agicultural Agents 2021 Annual Conference. Available online at: https://www.nacaa.com/ampic/2021/2021%20Proceedings%20LR.pdf (page 67)

Rhodes, J., S. Dill, A. Kness, E. Crowl, K. Nichols, S. Hirsh, D. Myers, A. Grev, E. Zobel, N. Little, B. Beale, N. Fiorellino, and D. Jarboe. 2021. University of Maryland Extension winter crop production meetings go virtual. In Proceedings: National Association of County Agicultural Agents 2021 Annual Conference. Available online at: https://www.nacaa.com/ampic/2021/2021%20Proceedings%20LR.pdf (page 207)

Grev, A.M. and S.B. Potts. 2021. A forage-based educational needs assessment for livestock and forage producers in Maryland. In Proceedings: American Forage and Grassland Council 2021 Annual Meeting. Savannah, GA. Available online at https://www.afgc.org/i4a/doclibrary/getfile.cfm?doc\_id=807

8. Collaborative Grants

W. Lamp as lead PI with S. Zebelo and D. Owens as co-PIs, 2020-2023. *Managing Agricultural Drainage Ditches for Conservation Biological Control on the Delmarva Peninsula*, USDA-SARE Novel Approaches Program, $197,728.

W. Lamp as lead PI with D. Hawthorne and A. Avanesyan as co-PIs, 2020-2021. *Identification of host plant use by the invasive spotted lanternfly (*Lycorma delicatula*) using next-gen DNA sequencing technology*, Maryland Agricultural Experiment Station $29,928.

Grev, A., S. Potts, and J. Semler. 2021-2022. *Effects of Nitrogen and Sulfur Fertility on Triticale Forage Protein Concentrations and Dairy Cow Performance*. Maryland Agricultural Experiment Station Competitive Grants Program. PI. Funding of $21,120 to support applied research related to triticale fertility management and feeding study.

Potts, S., A. Grev, and J. Semler. 2021-2022. *Effect of an Improved Grazing Management System on Dairy Heifer Performance*.  Maryland Agricultural Experiment Station Competitive Grants Program. Co-PI. Funding of $25,466 to support applied research related to grazing management for dairy heifers.

Goeringer, P., N. Fiorellino, J. Moyle, S. Potts, and A. Grev. 2021. *Assisting County and State Officials to Understand the Impacts of Agriculture in Maryland Part 3*. Maryland Grain Producers Utilization Board. Co-PI. Funding of $7,253 for team to produce self-paced, online agricultural-focused trainings.

Grev, A., A. Burk, S. Potts, S. Schoenian, B. Butler, E. Crowl, A. Kness, A. Leslie, R. Myers, and M. Perdue. 2020-2023. *Implementing Rotational Grazing Practices on Livestock Operations in Maryland*. Northeast SARE Research & Education Program. PI. Funding of $78,076 to educate livestock producers on rotational grazing practices and assist with implementation of these practices on their farm.

Grev, A., S. Schoenian, and J. Semler. 2020-2021. *Using Whole Grain to Increase the Profitability of Pasture-Raised Lamb*. Maryland Grain Producers Utilization Board. PI. Funding of $9,646 to complete pastured-raised lamb research project.

9. Graduate students

- Kutz, D. 2020. Agricultural drainage ditches as sources of beneficial spiders to enhance conservation biocontrol in adjacent croplands. Unpub. Masters thesis, Univ. of Maryland.

- Hartman, M. 2022. Odonata as beneficial predators in agricultural cropping systems. Master’s degree, University of Maryland.

**Michigan Report 2020-2021**

**Michigan State University**

1. **Impact Nugget**

None.

1. **New Facilities and Equipment**

None.

1. **Unique Project-Related Findings**

* Genetically modified reduced-lignin alfalfa varieties are generally low in lignin and high in digestibility but do exhibit variation where varieties are comparable to conventionally bred varieties.
* Perennial forage grass varieties may exhibit consistent ranking of heading dates across environments.

1. **Accomplishment Summaries**

Developing a Grass Maturity Index. Michigan joined a collaborative industry-driven project to develop a maturity index rating system for perennial forage grasses. This effort aims to identify reference grass varieties with a consistent ranking of maturity dates across environments. These reference varieties will ultimately be used to issue industry-standard maturity group rankings to released varieties. Preliminary data from three states (OR, IA, KY) were analyzed. Two Michigan sites were established in 2020/21. *Key Outcomes and other accomplishments realized:* Pearson rank correlation indicated stable ranking of varieties across locations.

Performance of Reduced Lignin Alfalfa. Two trials were established in 2017 to evaluate the relationship of harvest maturity to forage quality across conventionally-bred high-quality or yield and GMO reduced-lignin (HVX) alfalfa varieties. Yield and forage quality data were collected from 2018 to 2021. One trial had locations in six states (MI, WI, KS, OH, CA, UT) while the other had locations in southern and northern Michigan. *Key Outcomes and other accomplishments realized:* Second generation and commercially available HVX alfalfa varieties have similar yield and usually better fiber digestibility compared to standard high quality varieties, but some conventionally-bred varieties have comparable fiber digestibility.

Identifying factors to optimize establishment of alfalfa interseeded in corn. A four-state experiment (Wisconsin, Michigan, Pennsylvania, and Idaho) funded by NIFA-AFRP was conducted in 2018 and 2019 to evaluate management option to improve establishment of alfalfa in silage corn. A follow-up trial was funded from Project GREEEN in 2019. Summary statistics and discussion of results: Data collection is ongoing in 2019 and results will be evaluated at the end of the growing season. *Key Outcomes and other accomplishments realized:* Final results from this trial are reported from the Wisconsin state report.

Commercial Variety Testing. Michigan State University conducted variety trials on alfalfa, red clover, orchardgrass, fescues, perennial and Italian ryegrass, timothy, Kentucky bluegrass, and cover crops. *Key Outcomes and other accomplishments realized:* These data were distributed to farmers, industry and made available to other researchers for “big data” analysis.

1. **Impact Statements**

* Genetically modified reduced-lignin alfalfa varieties are generally low in lignin and high in digestibility but do exhibit variation where varieties are comparable to conventionally bred varieties.

1. **Published Written Works**

*Refereed Journal Articles: (past/present NCCC-031 members in bold)*

1. **Grabber, J.H**., H. Riday, W. Osterholz, **K. A. Cassida**, J. Williamson and M. Renz. 2021. Differential survival of alfalfa varieties interseeded into corn silage. *Crop Science* 61:1797-1808. doi: 10.1002/csc2.20465
2. **Sulc, R.M**., A.M. Arnold, **K.A. Cassida**, **K. Albrecht, M. Hall**, **D.H. Min**, X. Xu; D.J. Undersander, and E. van Santen. 2021. Changes in Forage Nutritive Value of Reduced-Lignin Alfalfa During Regrowth. Crop Sci. 61:1478–1487. doi: 10.1002/csc2.20366

*Proceedings Publications*

None

*Bulletins and Extension Factsheets:*

1. **Cassida, K.,** and J. Paling. 2021. *2020 Michigan Forage Variety Test Report.* MSU Forage Factsheet 21-01, 29 pages. Online 5/25/21.

*Farm Press Articles:*

1. Cassida, K. 2021. Virtual Great Lakes Forage & Grazing Conference recordings are available online. *Michigan Hay & Grazier*, Spring 2021, p 7.
2. Cassida, K.A. 2021. What is the future of forage variety testing? *Michigan Hay & Grazier*, Spring 2021, p.1
3. Thurlow and **Cassida.** 2021. Deciding what to do with “worn out” pastures *Michigan Cattleman*.
4. **Cassida, K**. 2021. MSUE Extension Announces New Online School for Hay Growers: Hay Production 101. *Michigan Hay & Grazier*. Michigan Forage Council, East Lansing, MI. Winter 2021, pp. 3.
5. Thurlow, K., and **K. Cassida**. 2021. Great Lakes Forage & Grazing Confernce Goes Virtual on March 11. *Michigan Hay & Grazier*. Michigan Forage Council, East Lansing, MI. Winter 2021, pp. 1.
6. **Cassida, K.,** and J. Paling. 2020. 2019 Michigan Forage Variety Test Report. Pp 14-23 in *Michigan Farm News*, Michigan Farm Bureau, Lansing, MI. Jan. 30, 2020. (circulation ~200,000)

*Web Articles:*

1. **Cassida, K**. 2020. *MSU Forage Connection*. [www.forage.msu.edu/](http://www.forage.msu.edu/) (Website)
2. **Cassida, K**., and K. Thurlow. Managing perennial pastures to withstand drought. MSUE AG News. Online 6/24, 2021. <https://www.canr.msu.edu/news/managing-perennial-pastures-to-withstand-drought>
3. Gould, K., and K**. Cassida**. Forage alternatives for livestock in drought years. *MSUE Ag News.* Online 6/4/21. <https://www.canr.msu.edu/news/forage-alternatives-for-livestock-in-drought-years>
4. **Cassida, K**. interviewed by D. Niemann. 2021. Episode 46 -Healthy weeds and poisonous plants. For the Love of Goats podcast. April 28, 2021. <https://thriftyhomesteader.com/healthy-weeds-and-poisonous-plants/>
5. **Cassida, K.A.** and K. Thurlow. 2021. Spring turn-out sets the tone for the entire grazing season. *MSUE Ag News*, online 4/14/21 <https://www.canr.msu.edu/news/spring-turn-out-sets-the-tone-for-the-entire-grazing-season> Republished in *Great Lakes Grazing Newsletter*, vol 10, Issue 2, April 2021.
6. **Cassda, K**. interviewed by N. Heslip. 2021. Michigan Hay Market Open to Growth. *Brownfield Ag News*. Online 3/2/2021, <https://brownfieldagnews.com/news/michigan-hay-market-open-to-growth/> (Recorded Interview)
7. **Cassida, K**. MSU Extension announces new online school for hay growers: Hay Production 101. *MSUE Ag News*, online Feb. 3, 2021. <https://www.canr.msu.edu/news/msu-extension-announces-new-online-school-for-hay-growers>

*Other Creative Works:*

* **Cassida, K.A.** 2019. Assessing Alfalfa Stands for Winter Damage. MSUE Field Crops Virtual Breakfast Meeting. Online. published 5/17/2019 <https://www.canr.msu.edu/resources/assessing-alfalfa-stands-for-winter-damage>, Accessed 8/31/19. (Webinar/podcast)
* Kapsenberg, R., **K.A. Cassida**, and T. Rice. 20210. AFGC Variety Test Survey, Amer. Forage & Grassl. Concil, Berea, KY.

1. **Scientific & Outreach Presentations**

*Abstracts and Posters:*

* Schaub, D, C Macaluso, **K Cassida**, J Schweihofer, E Recktenwald, B Makelaand R Ehrhardt. 2021. Evaluation of growth performance and plasma metabolites of lambs reared on cover crop and grain finishing systems. *2021 University Undergraduate Research and Arts Forum*, p. 3.

*Reports:*

* **Cassida, K.A**. 2021. NCCC-31 Annual Report. Madison, WI. July 21, 2021. Online.
* **Cassida, K.A.** 2021. Midwest Cover Crops Council Annual Report-Michigan. Online, Feb. 23, 2021. <http://mccc.msu.edu/wp-content/uploads/2021/02/MI_2020_-MCCC_Michigan-Report.pdf>

*Extension presentations:*

* Jan 10, 2021 – Cassida & Ehrhardt, Grazing Cover Crops, Part 1. Shepherds Weekend, MI Sheep Producers Assoc. Annual Conference Jan 8-10, 2021. Online.
* Jan. 10, 2021 – \*Macaluso, Ehrhardt & Cassida, Grazing Cover Crops, Part 2. Shepherds Weekend, MI Sheep Producers Assoc. Annual Conference Jan 8-10, 2021. Online.
* Jan. 15, 2021. Mix It Up in the Hayfield. *Virtual Crop & IPM Update*, online 1/15/21, <https://www.facebook.com/1477467478999687/videos/728482124456555/?__so__=watchlist&__rv__=video_home_www_playlist_video_list> (22 participants)
* Feb 2, 2021. Alfalfa winter hardiness and survival for great yields. Virtual IPM and Crop Update, Thumb version.
* Feb 16, 2021. Considering the Cost-Benefit Conundrum for Use of High-Quality Alfalfa Varieties. *Virtual Midwest Forage Association Symposium*. Feb. 16-17, 2021, virtual. (**INVITED SPEAKER**)
* Feb 17, 2021. How do we get to the bottom of the alfalfa autotoxicity problem? *Virtual Midwest Forage Association Symposium*. Feb. 16-17, 2021. (**INVITED SPEAKER**)
* Feb. 23, 2021. Michigan Cover Crop Research Update. *Midwest Cover Crops Conference*. Feb. 23-24, 2021,
* March 2, 2021. Introduction. *Hay Production 101*, MSUE online Short Course. (127 partipicipants)
* March 4, 2021. What to Grow: Species, Varieties, and Forage Quality. *Hay Production 101*, MSUE online.Short Course. (127 partipicipants)
* March 6, 2021. Is it a weed or is it feed? *Sheep and Goats for Small Farms Day*, webinar format. (83 live) (**INVITED SPEAKER**)
* March 11, 2021. What to Grow: Species, Varieties, and Forage Quality. *Hay Production 101*, MSUE Short Course, online. (127 partipicipants)
* Mar 11, 2021. MSU Forage Research Update. *Great Lakes Forage & Grazing Conference*, webinar format. (114 participants) online <https://www.afgc.org/i4a/pages/index.cfm?pageid=3296>
* March 16 2021. Pest Management. *Hay Production 101*, MSUE Short Course, online. (127 participants)
* March 18, 2021. Cassida, Kaatz, and Harrigan. Harvest Management-Part I. *Hay Production 101*, MSUE Short Course, online. (127 participants)
* March 18, 2021. **K.Cassida**, D. Miller, & E. Creech. Best Management Practices for Stand Establishment. *Alforex Alfalfa Livestream..* Online Mar. 25, 2021, <https://www.youtube.com/watch?v=pNtLpPKfiGY> (**INVITED SPEAKER**)
* March 23, 2021. Cassida and Harrigan. Harvest Management-Part II. *Hay Production 101*, MSUE Short Course, online. (127 participants)
* June 17, 2021. Forage Supply & Management in a Drought. *MSUE Virtual Breakfast*. (100 synchronous views, URL <https://www.canr.msu.edu/videos/forage-management-supply-in-a-drought>, 53 *YouTube* views 9/3/21 )
* July 7, 2021. Expanding Irrigated Crop Options: Annual Forages. *MSUE Let’s Talk Irrigation webinar Series*. (11 participants)
* June 22, 2021. Tips for putting on a forage conference. AFGC Affiliate Workshop. (**INVITED SPEAKER)**
* July 21, 2021. NCCC-031 Michigan Research Update. Online synchronous.
* Aug. 12, 2021. Late-season alfalfa management. MSU E Virtual Breakfast. (100 synchronous views, URL https://www.canr.msu.edu/videos/late-season-alfalfa-management, 40 remote views 9/3/21)
* Sept 2, 2021. The forage connection: redefining relevance in a changing world. PSM/Hort Seminar. Online synchronous.
* Sept 21, 2021. Introduction to grazing (Thurlow and Cassida). Beginner Grazing School. Online synchronous.
* Sept 23, 2021. Graziers are grass farmers. Beginner Grazing School. Online synchronous.
* Sept 30, 2021. Pasture establishment and renovation. Beginner Grazing School. Online synchronous.

1. **Collaborative Grants** *(NCCC31 members bolded)*

* **Picasso, Berti,** **Cassida**, Finan, **Hannaford, Lamp**, & Stevens. 2021. **F**ostering **r**esilience and **e**cosystem **s**ervices **i**n **l**andscapes by **i**ntegratingdivers**e** pere**n**nial **c**ircularsyst**e**ms. NIFA-AFRI-SAS. $10, 999, 979. FUNDED

1. **Graduate Students**

* Logan Thompson (PhD 2021)
* Sarah Drumm (MS 2021)
* Cathyrn Macaluso (MS 2021)

**North Dakota Report 2020-2021**

**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 cropping systems has allowed us to get funding to continue research in forages.

**2. New Facilities and Equipment:**

None

1. **Unique Project Related Findings:**

**4. Accomplishments summaries:**

***Alfalfa-corn intercropping:*** It is a good option for farmers that grow corn silage and alfalfa. In 2020, experiments with corn-alfalfa intercropping at 60 and 30” row spacing were conducted. Results indicate corn at 60” has about 18% lower yield than corn at 30 inches without alfalfa. With alfalfa intercropping the reduction was only 11% and establishment of alfalfa at 60-inch corn was better than at 30”. Alfalfa and corn roots were separately analyzed for their AM colonization. Compared with Prosper, the AM colonization of alfalfa was consistently higher at Hickson (~55% to 60% in Hickson, and ~30% to 40% in Prosper), but the AM colonization in the plots in which alfalfa was planted alone did not differ from the plots in which alfalfa was planted with corn. While the alfalfa colonization in Hickson was higher than in Prosper, the AM colonization of corn did not differ at both sites, and was with ~25% to 35% relatively low. The spacing between the corn rows (30 or 60”) or the intercropping with alfalfa did not affect the AM colonization of the corn plants.

***K fertilization and its impact on yield, quality, and winter hardiness of alfalfa***

### Two separate sites were established for this study. The two locations differ in their clay mineralogy and their smectite-to-illite ratio. With a smectite to illite ratio greater than 3.5, the soil at Milnor immobilizes potassium, while the soil at Lisbon with a smectite to illite ratio less than 3.5, allows potassium to be more mobile. The three alfalfa varieties Presteez RR, Stratica RR, and L-450 RR were used for this study. Each of the varieties has a different fall dormancy score. Three different K treatments were applied: 0, 168, and 336 kg K2O ha-1 in single- and split-application. Half of the experimental units were stressed by harvesting mid-September, while the other half was non-stressed by harvesting in October. Soil K was higher with a split-application, compared with a single-application of K at the same rate. Total seasonal forage yield was significantly lower when no K was applied. Stressed alfalfa had lower root protein in both years and starch was lower in Milnor 2019 and Lisbon 2020 compared with the non-stressed treatment. We also analyzed the arbuscular mycorrhizal (AM) colonization of the roots. Independent of the location (Lisbon and Milnor), the K fertilization, and the variety, the plants showed a similar mycorrhizal colonization rate of 50 to 60% in 2019. Compared with 2019, the AM colonization in 2020 of the different varieties increased particularly in Lisbon. While the AM colonization at Milnor did not differ, the AM colonization of the varieties L-450RR and Stratica increased at high K fertilization rates and the colonization rate of Presteez at low K fertilization rates and reached up to 75%.

### *Identify AM fungal communities and Rhizobia in alfalfa populations in North Dakota and South Dakota*

### In 2021, alfalfa roots were sampled at 30 locations in North Dakota and 22 locations in South Dakota between May 25-29. Samples for this experiment were taken from different sites in North Dakota (Fargo, Hickson, Milnor, Lisbon, Carrington, Sykeston, Williston, Charbon Township, Watford City, Dunn Center, Dickinson, Richardton, Mott, Hettinger, SD National Grasslands, New Leipzig, Strasburg, Linton, Napoleon, Alkaline Lake, REC Streeter) that were planted between 1988 (Napoleon) and 2020 (Hickson) and differ in their management practices. The samples in South Dakota were taken from Beresford, Tyndall, Mt. Vernon, Baltic, Madison, Wilmot, Clark, Ipswitch, Selby, Timber Lake, Buffalo, Newell, Spearfish, Oelrichs, Long Valley, Colome, Pierre, Ree Heights, and Brookings). Soil samples were taken at each site and N-NO3, P, K, organic matter, pH, and electrical conductivity were evaluated. Samples are currently being prepared for AMF colonization analysis and metagenome analysis.

***Perennial grasses winter-hardiness evaluation:***

Twenty perennial forage grasses from different species and varieties were planted in 2020 in Prosper and Fargo. Forage yield differences in the seeding year between varieties of the same species were not significant. The large significant difference between the variety Esquire and the other two cultivars of perennial ryegrass can likely be attributed to ‘Esquire’ having higher incidence of leaf rust early in the seeding year.

In the first production year, winter survival was much greater in Fargo than in Prosper across species and varieties. There were not great differences among varieties within a same crop. Meadow and smooth brome had the highest survival of all grasses. Perennial ryegrass survival was less than 10% with not clear significant differences among varieties. Intermediate wheatgrass varieties had the greatest yield in the first cut of 2021 ranging between 4,500 and 6000 lbs/acre

***Life cycle assessment (LCA) of integrated cropping systems for food, feed, and energy****:* Treatments with intersseeded cover crops (camelina, field pennycress and rye) had (a) lower eutrophication potential and water soil erosion, and (b) lower GWP if the cover crop was not fertilized with nitrogen. Winter camelina and pennycress were more effective than rye in reducing soil losses, while the three cover crops provided similar results for eutrophication potential. The results for the SOC variation were mixed, but the sequence with rye had the best performance in all locations. The results of this study suggest that the introduction of winter camelina and field pennycress as winter-hardy cover crops has a strong potential for reducing the environmental impacts of the maize-soybean rotation in the U.S. upper Midwest. However, a better field management of nitrogen fertilization and crop residues of these cover crops in a relay-cropping system is needed to make them a viable and sustainable agricultural practice.

**4. Impact Statement**

The forage program at NDSU **is the only program that provides non-biased information to farmers** on the performance of forages in ND. Forages acreage, without including CRP or native rangeland, was 3,400,986 acres in 2019. **Forages are the third most important crop in acreage in ND** after wheat and soybean. Diverse studies in alfalfa management conducted by this project have demonstrated that forage yield can be easily increased on average at least by 0.3 ton/acre/yr. Alfalfa acreage in ND in 2019 was 490,632 acres and alfalfa-grass mixtures 920,454 acres. An increase in forage yield of 0.3 tons/acre/year x 1,411,086 acres (alfalfa & alfalfa-grass) @ $120/ton of hay equals an economic impact of **$50,799,096/yr.** Alfalfa-corn intercropping allows alfalfa to be established in the corn year. This system increases alfalfa yield in Year 2 by 2.5 tons/acre compared with a spring-seeded alfalfa with a net profit of $80/acre. The acres of corn silage-alfalfa rotation in ND are about 150,000 acres x $80= $**1,200,000** in monetary impact. Using wide-row corn (60”) to establish alfalfa, although decreases corn yield in 15-20%, the established alfalfa the following year yields 3 tons/acre with a net profit of about $100/acre. If we consider approximate 150,000 acres are contemplating to have this system $150,000 x $100= **$1,500,000** inmonetary impact.

The impact of bioenergy crops research it is hard to value monetarily, since there is not commercial production of energy crops in ND yet. But FS can yield up to 10 tons DM/acre at $30-50/ton for biomass feedstock gross income will be $300-500/acre. In 2019, FS acreage increased from 35,843 acres in 2017 to 51,488 acres in 2019, at $50/ton value by 5 tons/acre (2 cuts) as feed, the economic impact equals **$12,872,000/yr.**

Cover crops acreage increased 89% from 2012 to 2017 in North Dakota, with a total of 404,267 acres according to the last census. The research of interseeding cover crops into standing corn, soybean, and sugarbeet has indicated cover crops retain-30-50 lbs of N in their biomass preventing nitrate leaching off the root zone of the cover crops. With a very conservative N credit of legume cover crops of only 10 lbs N/acre, the economic value of reducing the fertilization in corn in 3,425,105 acres x 10 lbs N/acre saving x $0.35 lb N, is **$11,987,868/yr.** Cover crops forage value can add $30/acre revenue by grazing. If only 1% of the wheat acreage (7,363,522 acres) was planted to cover crops for grazing after harvest, the economic impact would be **$2,209,057/yr**.

**In summary, the forages, biomass, and cover crops project at NDSU impacts the state’s economy by: a) increasing alfalfa and other forages yield, b) decreasing N rates in cash crops, c) increasing soil health and crop yields in the long term, and d) providing additional forage for grazing in the fall.**

**Total potential economic impact of the forage & biomass production project to the state is about $80,568,022 annually.**

5. Published written work

*Peer-reviewed publications*

1. Patel, S., C.A. Bartel, A.W. Lenssen, K.J. Moore, and **M.T. Berti.** 2021. Stem density, productivity, and weed community dynamics in corn-alfalfa intercropping. Agronomy 2021, 11,1696. https://doi.org/10.3390/agronomy11091696
2. **Berti, M.T**. A. Cecchin, D.P. Samarappuli, S. Patel, A.W. Lenssen, K.J. Moore, S.S. Wells, and M.J. Kazula. 2021. Alfalfa established successfully in intercropping with corn in the US Midwest Agronomy 2021, 11, 1676 <https://doi.org/10.3390/agronomy11081676>
3. Schmitt, M. **M.T. Berti,** D. Samarappuli, and J. Ransom. 2021. Factors affecting the establishment and growth of cover crops intersown into maize (*Zea mays* L.). Agronomy 11: 712. <https://doi.org/10.3390/agronomy11040712>
4. Kandel, H. D.P. Samarappuli, K. Johnson, and **M.T. Berti**. 2021. Soybean relative maturity, not row spacing affected interseeded cover crops biomass. Agriculture 11 (5): 441 https://doi.org/10.3390/agriculture11050441
5. **Berti, M.T.,** J.Lukaschewsky, and D.P. Samarappuli. 2021. Intercropping alfalfa into silage maize can be more profitable than maize silage followed by spring-seeded alfalfa. Agronomy 11(6), 1196; <https://doi.org/10.3390/agronomy11061196>
6. Cecchin, A., Pourhashem, G., R.W. Gesch, A.W. Lenssen, S. Patel, Y. Mohammed and **M.T. Berti**. 2021. The environmental impact of ecological intensification of a cropping system in the U.S. Upper Midwest. Sustainability 13: 1696. https://doi.org/10.3390/su13041696
7. Cecchin, A., Pourhashem, G., R.W. Gesch, A.W. Lenssen, S. Patel, Y. Mohamed, and **M.T. Berti**. 2021. Environmental trade-offs of relay-cropping winter cover crops within maize and soybean. Agric. Systems 189:103062
8. Patel, S., A.W. Lenssen, K.J. Moore, Y.A. Mohammed, R.W. Gesch, M.S. Wells, B.L. Johnson, **M.T. Berti**, and H.L. Matthees. 2021. Interseeded pennycress and camelina yield and their influence on row crops. Agronomy J. doi: 10.1002/agj2.20655

*Scientific and Outreach Presentations*

1. Cecchin A. and **M.T. Berti.** 2021. Is ecological intensification of agriculture really sustainable? 27th International Sustainable Development Research Society (ISDRS) conference, Faculty of Science, Technology and Media, Mid Sweden University, Sweden, 11-15 July 2021 (virtual)
2. Cecchin, A., and **M.T. Berti.** 2021. Environmental and economic trade-offs of introducing winter camelina in the upper Midwest of the USA: A review European Biomass Conference, Marseille, France 27-29 April 2021. (virtual)
3. **Berti, M.T**., D.P. Samarappuli, A. Cecchin, and A. Wittenberg. 2021. Integration of biomass sorghum in current cropping systems of the northern Great Plains of the USA to enhance ecosystem services delivery. European Biomass Conference, Marseille, France 27-29 April 2021. (virtual)
4. Spiess, J., D. McGranahan, C. Gasch, B. Geaumont, **M.T. Berti,** and T. Hovick. 2021. Benefits of using prescribed fire in working rangeland ecosystems: Takeaways from a patch-burn grazing study in southwestern North Dakota. Black Hills Area Botany & Ecology Workshop (BHABEW XVIII) March 8-10, 2021.
5. Spiess, J., M. Wanchuk, D. McGranahan,  B. Geaumont, **M.T. Berti**, K. Sedivec, T. Hovick, and R. Limb. 2021. The grass is greener in the burned patch: livestock responses to variable forage nutritive value on patch-burn grazing pastures in North Dakota. SRM 2021: Range Livestock Production and Behavior.
6. **Berti, M.T.**, D. Samarappuli, S. Cabello, A. Wittenberg, S. Bibby, K. Mozea, H. Kandel, J. Ransom, A. Wick, D. Franzen, J.V. Anderson, and J. Haley. 2021. Cover Crops, North Dakota Annual Report. Midwest Cover Crop Council Conference. London, Ontario. 23-24 February 2021. Virtual.
7. **Berti,** M.T. 2021. Does nitrogen in cover crops biomass cycles back to the next crop? 13th Nutrient Management Conference. Minnesota Agricultural Water Resource Center (virtual) 16 February 2021. ***Invited speaker*** (242 participants).
8. **Berti, M.T.** 2021. Why is potassium so important in alfalfa?. Alfalfa-U series. High Plains Journal 16 February 2021 (virtual). Available at <http://www.hpj.com/alfalfau>. ***Invited speaker.*** (145 participants).
9. Greenberg, A., **M.T. Berti**, D.P. Samarappuli, A. Peterson, S. Cabello, A. Wittenberg, and K. Mozea. 2021. Potassium fertilization and its impact on yield, quality, and winter hardiness of alfalfa. American Forage and Grassland Council Conference, Savanah, GA (virtual) 11-12 January 2021.
10. Bibby, S., **M.T. Berti**, A.F. Wick, D.P. Horvath, J.V. Anderson, A. Wittenberg, A. Greenberg, and K. Mozea. 2021. Corn-alfalfa intercropping with different row spacings. American Forage and Grassland Council Conference, Savanah, GA (virtual) 11-12 January 2021
11. **Berti, M.T.** 2020 Integrating cover crops into cropping systems for better soil health- What works what doesn’t? Soil Management Summit University of Minnesota. Virtual Conference. 15-16 December 2020. ***Invited***
12. **Berti, M.T.** 2020. Diversification of production systems for sustainable production of food and renewable energy while enhancing soil health. II Congreso de Desarrollo Territorial 2020: Promoviendo la Sustentabilidad. Ahuacatlán, Puebla, Mexico, 21-23 October.(Virtual presentation) ***Invited plenary speaker.***
13. **Berti, M.T.** 2020. Biomass sorghum: the most promising energy crop in the northern Great Plains. Association for the Advancement of Industrial Crops(AAIC) Webinar Series 8-9 September, 2020. Virtual conference. ***Invited speaker***

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

1. **Berti, M.T.** 2021. Can I feed cows with drought affected crops? Forage Focus Magazine August 2021. Midwest Forage Association, St. Paul, MN
2. Sigdel, S. A. Chatterjee, and **M.T. Berti.** 2021. Adoption of cover crop interseeding within sugarbeet in the Red River Valley. Crops and Soils Magazine, May-June 2021. American Society of Agronomy doi: 10.1002/crso.20117
3. Kandel, H. and **M.T. Berti.** Foxtail millets for hay. 2021. Crop and Pest Report no. 5, May 27, 2021 NDSU Extension.
4. Sedivec, K. **M.T. Berti**, and E. Crawford. 2021. Producers may be dealing with winter-killed alfalfa. NDSU Extension and Ag Research News. 10 May 2021 Available at: https://www.ag.ndsu.edu/news/newsreleases/2021/producers-may-be-dealing-with-winter-killed-alfalfa

**7*. Collaborative grants***

NAFA 10/2021-09/2022. Identification of rhizobium inoculants tailored for performance with new alfalfa varieties and diverse soil types. $74,325 Co-PI

Midwest Forage Association 05/2021-04/2022. Testing new high quality perennial cool-season forage grasses with improved winter hardiness and persistence. Year 2. $2,935, PI

ND Corn Utilization Council 07/2021-06/2022. Comparing and prioritizing conservation practices to enhance soil fertility and productivity in corn cropping systems. $30,578. PI.

**8. Graduate students**

**McKayla Neubauer, MS** Molecular changes in the transcriptome of camelina and alfalfa under competition. Expected graduation December 2022. Advisor: Berti

**Austin Krakaul, MS:** Alfalfa-corn intercropping in North Central North Dakota. Expected graduation December 2023. Advisor: Berti

**Mikayla Tabert, MS:** Establishing alfalfa and cover crops in intercropping with sunflower. Expected graduation December 2023. Advisor: Berti

**Samuel Bibby, MS:** Alfalfa-corn intercropping a two- row spacing of corn. Expected graduation August 2022. Advisor: Berti

**Kenneth Mozea, MS**: Full-season cover crops grazing mixtures. Expected graduation December 2021. Advisor: Berti.

**Amy Greenberg, MS:** Potassium fertilization in alfalfa. Graduated May 2021. Advisor: Berti.

**Jonathan Spiess, PhD**: Livestock responses to variable forage nutritive value on patch-burn grazing pastures in North Dakota. Advisor: McGranahan

**Ohio Report 2020-2021**

**The Ohio State University**

1. Impact Nugget  
The forage group at The Ohio State University is conducting research related to 1) understanding how crop-livestock agroecosystems function and how management of those systems affects resilience in a changing climate at the field and food system scale, 2) new forage technologies and management practices that will improve sustainability of forage and grazing systems, and 3) ecology of running buffalo clover, a native legume.

2. New Facilities and Equipment

* Gas chromatograph – Shimadzu GC2014
* Leaf area meter – Li-Cor LI-3100C

3. Unique Project Related Findings

* Running buffalo clover has high shade tolerance, readily propagates by stolons, and has excellent nutritive value; however, its potential as a forage species in native pastures in not yet known.

4. Accomplishment Summaries

A rotational stocking strategy to maintain pasture sward heights that optimize sheep and forage responses. (Verhoff, Sulc, Chiavegato, and Barker)  
An experiment was established in May 2021 in a tall fescue dominant pasture to compare animal and forage sward productivity under (i) “rotatinuous” (RN) stocking management in which lambs graze off 30% of the sward height and (ii) traditional rotational stocking management (RT) in which lambs graze off 60% of the sward height. The goal is to have pre-grazing height of the rotatinuous treatment near the optimal height for maximizing sheep instantaneous intake on tall fescue, as reported by Szymczak et al. (2020), Studies have demonstrated that pasture structure limits forage intake (consumption) of animals on pasture, indicating that management strategies can be designed to maximize bite mass and forage intake per unit of grazing time that promote both high animal production and landscape and ecosystem. Previous studies with diverse forage species have shown that forage intake on pasture begins to decline rapidly in cattle after 40% of the initial sward height is removed and in sheep after 30% of the initial sward height is removed. Therefore, we hypothesize that a rotational stocking management system based on only 30% sward height (lenient pasture utilization) removal should increase lamb intake and weight gain compared with the traditional approach of a removing 60 to 70% of the sward height (high pasture utilization).

Ecology of running buffalo clover. (Barker)  
The Ohio State University has collaborated with the Ohio Department of Natural Resources (ODNR) and Great Parks of Hamilton County (City of Cincinnati) to collect and propagate running buffalo clover (RBC) (*Trifolium stoloniferum*) plants from natural sites in Ohio. Running buffalo clover is a federally protected, endangered legume species. Studies to date have found RBC has high shade tolerance, readily propagates by stolons, and has excellent nutritive value. Its potential as a forage species in native pastures is not known, however, insufficient plant material is available for the conduct of research studies. This study has procured up to 25 RBC stolons from each of twelve sites in Ohio, and successfully cloned approx 1000 plantlets from these stolons. Of these, 750 plants served as a resource for replanting back into natural areas (especially for small populations having <50 plants). Another 250 plants will be a resource for genetic analysis in 2019. The plants will also be used for seed increase in 2019.

Soil carbon inputs and storage in flooded pasture fields of Southern Ohio. (Chiavegato et al.)

An experiment was established in May 2020 in Jackson, OH to evaluate above and below ground inputs of organic carbon and soil carbon storage in different forage species combinations, under flooding-prone and non-flooding prone pastures, and in a non-flooding prone hayfield. The treatments in flood prone and non-flood prone grazed plots were composed of: i) control (dominated by tall fescue, orchard grass and red and white clover); ii) winter cover-crops, rye and oat; iii) a cool-season species mixture established by drilling in tall fescue, Kentucky bluegrass, orchard grass, red and white clover; and iv) cool-season + warm-season mixed pasture. The hayfield was dominanted by tall fescue with random lesser amounts of clover and orchardgrass. Aboveground dry matter mass is being monitored throughout the 2021 growing season and roots were collected in mid-summer 2021 and will be collected again in late fall 2021 to determine carbon inputs. A preliminary analysis of the soil carbon stocks (0-100 cm depth) showed higher values in the grazed pastures (average of 112.2 Mg C ha-1) relative to hayfield (102.1 Mg C ha-1). This difference occurred mainly due to increased C content in the first 20 cm of soil in grazed plots (30.4 *vs* 23.2 g dm-3 in the hayfield). Flooded grazed plots had decreased C storage (0-100 cm) of 8.8%, mainly due to reduced C contents on the 0-20 cm soil depth. The aboveground dry matter in mid-summer was 20% lower in the flood prone area compared with the non-flood prone pasture, and probably this lower productivity is leading to reduced carbon inputs, and therefore, reduced carbon storage in flood prone soils.

Effect of recurring, short-term flooding on soil, pasture and environmental characteristics of grazed and hay pastures. (Chiavegato et al.)

A two-scenario project has been established at two different locations in Ohio, southern (Jackson, OH – Scenario 1) and northwestern (Jenera, OH – Scenario 2). In Scenario 1, flood-prone and non-flooded grazed and hay pastures are composed of tall fescue, with random occurrence of red clover, and orchard grass. Three treatments were identified for that scenario at the farm in 2019: flood and non-flood prone pastures for grazing and non-flood prone hay field. In Scenario 2, hayfields and croplands will be monitored at a commercial partnering farm in the Western Lake Erie Watershed region. Croplands are predominantly on flat landscapes and the establishment of forage cover on the environmentally sensitive areas is encouraged through the Ohio Working Lands Buffer Program administered by the Ohio Department of Agriculture and local Soil and Water Districts. Forage areas were established in 2019 under this program, and farmers can harvest and remove forage. Three treatments were identified for this scenario: three levels of flood prone hay fields (non-flood, low flood and high flood prone). The specific objectives are to monitor GHG emissions from soils, soil C, N and organic matter content, pasture diversity, and forage quality and quantity in both scenarios. We hypothesize that flood-prone pastures for grazing and for hay will have lower forage quality and higher GHG emissions in comparison with non-flood prone pastures for grazing and for hay, due to increased water content in the soil.

Native warm season grasses to enhance pasture resilience to climate change (Chiavegato et al.)

This project will focus on identifying best management practices (BMPs) to establish native warm-season grasses (NWSG) in pastures at four different locations in Ohio: Jackson, Caldwell, Flushing, and Georgetown. The objective of this study is to assess morphogenic and structural characteristics of NWSG species when there are different plant establishment strategies. This proposal has extension and research objectives. The extension objective is to determine the best management practices for establishment of the warm‐season grass species tested. The outcomes are extension publications and field days to communicate the BMPs and show the demonstration plots. Four NWSG will be tested, switchgrass, indiangrass, big bluestem, and eastern gamagrass, using conventional and non-chemical practices for stand establishment. Big bluestem and indiangrass will be planted in mixtures which is the conventional practice of most beef producers. Switchgrass and Indiangrass will be planted individually. The non-chemical practices will be used to address organic producer needs. Three treatments will be tested, with different strategies of summer and winter cover crops in rotation with the NWSG.

Comparing the environmental tradeoffs and synergies of alternative modes of integrating livestock into cash grain cropping systems (Jackson-Smith et al.)

The project’s goal to identify pathways to improve the performance of integrated crop‐livestock systems, document opportunities and barriers to the expansion of the most promising approaches, and to develop recommendations for public and private interventions that can accelerate their use. To achieve these goals, we will pursue five interrelated objectives: 1) Quantify the diverse environmental outcomes associated with each approach to livestock‐crop integration under working farm conditions; 2) Assess the animal welfare and human health risks and benefits associated with more widespread use of manure and greater integration of livestock in cash grain cropping systems; 3) Develop whole farm models to quantify 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 that limit adoption of each approach on regional livestock and cash grain farms, and 5) Use a participatory on‐farm approach throughout to better integrate research and extension/outreach activities. We will collaboratively develop recommendations for public policies and private supply chain programs to incentivize the most economically and environmentally beneficial approaches to livestock‐crop integration.

5. Impact Statements

Soil carbon inputs and storage in flooding prone pasture fields of Southern Ohio.

The use of grazing areas with the inclusion of either winter annual grasses or cool-season species has shown the potential to increase aboveground productivity. As flood prone areas have lower soil carbon stocks, the used of more diverse pasture can be a strategy to increase soil carbon sequestration in the long run.

Effect of recurring, short-term flooding on soil, pasture and environmental characteristics of grazing and hay pastures.

The main goal of this research is to understand the effects of recurring, short-term flooding on GHG emissions from soils, and on the soil and forage characteristics in pastures for grazing and for hay. Once we know these impacts, we will be able to explore strategic pasture management options to increase pasture resilience and productivity (longer-term goal).

6. Published Written Works

*Refereed publications*

Quinby, M.P. ; Nave, R.L.G.; Sulc, R.M.; Castillo, M.S.; Bates, G.; McIntosh, D.; Schneider, L. (2021). Comparison of alfalfa mixed with tall fescue and bermudagrass on forage accumulation, botanical composition, and nutritive value. Crop Sci. <https://doi.org/10.1002/csc2.20461>

Dominschek, R.; Barroso, A.A.M.; Lang, C.R.; Moraes, A; Sulc, R.M.; Schuster, M.Z. (2021). Crop rotations with temporary grassland shifts weed patterns and allows herbicide-free management without crop yield loss. J. of Cleaner Production Volume 306. <https://doi.org/10.1016/j.jclepro.2021.127140>.

Sulc\*, R.M., A.M. Arnold; K. A. Cassida; K. A. Albrecht; M. H. Hall; D. Min, X. Xu; D. J. Undersander; E. van Santen. 2021. Changes in nutritive value of reduced lignin alfalfa during regrowth. Crop Sci. 61:1478-1487. <https://doi.org/10.1002/csc2.20366>

Sulc, R.M.; Lamp, W.O.; Buntin, G.D. (2020) Insect management. p. 535-550 In Moore, K.J.; Collins, M.; Nelson, C.J.; Redfearn, D.D. (eds.) Forages: The Science of Grassland Agriculture, Vol. II. 7th ed. Wiley Blackwell, West Sussex, UK.

Szymczak, L.S.; A.de Moraes; R.M. Sulc; A.L.G. Monteiro; C.R. Lang; R.F.; Moraes; D.F.F. da Silva; C. Bremm; P.C.F. Carvalho. (2020). Tall fescue sward structure affects the grazing process of sheep. Sci Rep 10, 11786. <https://doi.org/10.1038/s41598-020-68827-0>.

Casler, M.D.; Lee, D.; Mitchell, R.B.; Adler, P.R.; Sulc, R.M.; Johnson, K.D.; Kallenbach, R.L.; Boe, A.R.; Mathison, R.D.; Cassida, K.A.; Min, D.; Moore, K.J. (2020). Nitrogen demand associated with increased biomass yield of switchgrass and big bluestem: implications for future breeding strategies. Bioenerg. Res. 13:120-131https://doi.org/10.1007/s12155-019-10081-y.

Da Silva, S.C.; Bueno, A.A.O.; Carnevalli, R.A.; Silva, G.P.; Chiavegato, M.B . (2020). Nutritive value and morphological characteristics of Mombaça grass managed with different rotational grazing strategies. JOURNAL OF AGRICULTURAL SCIENCE, 157, 595-598. doi: 10.1017/S0021859620000052.

Congio, G.F.S., Bannink, A., Mogollon, O.L.M., Hristov, A.N., Chiavegato. M.B., et al. 2021. Enteric methane mitigation strategies for ruminant livestock systems in the Latin America and Caribbean region: A meta-analysis. Journal of Cleaner Production, 321, 127693.

<https://doi.org/10.1016/j.jclepro.2021.127693>

*Proceedings publications*

None

*Bulletins and Extension Factsheets*

Sulc, R.M., Weiss, W., Hartschuh, J., Lewandowski, R. (2020). *Harvesting winter annual forages for dairy.* Dairy Issue Briefs #38-20. Ohio State University Extension. Available at <https://dairy.osu.edu/dibs>

7. Scientific and Outreach Presentations

*Abstracts , symposium and conference presentations*

None

8. Collaborative Grants

Culman, S., Haden, V.R., Sprunger, C.D., Sulc, R.M., Ward, B.W. 9/2019 - 8/2023. Organic dual-use perennial grain crops: Pathways to profitability and soil health. USDA-NIFA OREI. Total Award $1,776,905 Grant.

**Chiavegato, M. et al. 5/2021 – 8/2022. Native Warm Season Grasses to Enhance Pasture Resilience to Climate Change. GREENACRES FOUNDATION. Total Award $28,400 Grant.**

**Jackson-Smith, D., Chiavegato, M; Parker, A; Culman, S; Sprunger, C; Lyon, S; Wang, H. (2020). Comparing the environmental tradeoffs and synergies of alternative modes of integrating livestock into cash grain cropping systems. USDA-NIFA-AFRI . ($999,408 total).**

9. Graduate students

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

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

Miquilini, Marina. MS. Expected graduation date: December 2022. Effect of recurring, short-term flooding on soil, pasture and environmental characteristics of grazing and hay pastures.

Rai, Qulina. PhD. Expected graduation date 2025. Comparing the environmental tradeoffs and synergies of alternative modes of integrating livestock into cash grain cropping systems.

Rodriguez, Chelsie. MS. Expected graduation date 2023. TBD.

**Oregon Report 2020-2021**

**Oregon State University**

1 **Impact Nugget**

*Development of new methodology or approaches:*

• Utilizing molecular biology techniques to identify alfalfa forage quality genes.

• Incorporating reseeding annual legumes into perennial pastures to improve forage yield and quality and improve animal performance.

*Implementation of solutions or adoption of recommendations developed:*

• Matching forage species characteristics with irrigation water rights and producers’ specific objectives to achieve agricultural sustainability while conserving endangered species habitats.

*Cleaner environment and healthier communities:*

• Increasing the use of forage species such as birdsfoot trefoil, plantain, and chicory in Oregon grazing pastures to reduce methane emissions, urine leaching to the groundwater, and increasing atmospheric nitrogen fixation to lower nitrogen fertilizer demands.

**2. New Facilities and Equipment: NA.**

**3. Unique Project Related Findings: NA.**

**4. Accomplishment Summaries**

Collaborative Efforts: Oregon State University Extension and Research faculty working together through a “Forage and Livestock Systems” Extension (and Research and Teaching) Working Group. The mission of this working group is to increase collaboration on planning and execution of high priority projects and contributing to the many integrated scientific disciplines involved in sustainable forage-livestock systems.

The “Oregon Forages” website (https://forages.oregonstate.edu/oregon) is developing and presenting comprehensive content of forage and livestock topics and segments devoted to the interrelationships among soil, water, plant, animal, and human health and the economic and social implications of 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. 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. This past year has used funding from the Extension Program Leader to the Forage Work Group to develop nearly-completed drafts for 11 annual forage fact sheets and initial drafts for numerous other species. A uniform template has been developed and extensive content has been developed. Key components of the template include: 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. Internal and external reviews have been solicited, received, and incorporated. The primary challenges remaining for completion of these fact sheets include the Seasonal Production Profiles and Phenological Development graphics based on photo-thermal time. This information has not been developed to date, despite hundreds of years of location-based experimentation.

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.

Guojie Wang: Evaluation of forage species for increased water use efficiency and seasonal forage production to develop systems that balance agricultural production needs for irrigation water with ecological needs for ecosystems services including wildlife and fish habitat.

Ruijun Qin: Evaluating the effect of the intercropping of alfalfa and grass on the hay production, quality, and economy under two water regimes.

**5. Impact Statements**

**6. Published Written Works**

*Refereed publications*

Lin, S., C.A. Medina, S. Norberg, D. Combs, G.J. **Wang, G.** Shewmaker, S. Fransen, D. Llewellyn & L.X. Yu. 2021. Genome-wide association studies identifying multiple loci associated with alfalfa forage quality. Frontiers in Plant Science/Plant Breeding 12: 648192. doi: 10.3389/fpls.2021.648192.

Yang, Yungui, Yanyan Lin, Lu Zhao, Xuemei Yang, Ting Guo, and **David B. Hannaway**. 2021. Influence of ensiling additives on silage quality of several oat cultivars. International Journal of Science 8(2): 23-31. <http://www.ijscience.org/download/IJS-8-2-23-31.pdf>

**Wang, G.J.,** G. Bobe, S.J. Filley, G.J. Pirelli, M.G. Bohle, T.Z. Davis, G.L. Banuelos & J.A. Hall. 2021. Effects of springtime sodium selenate foliar application and NPKS fertilization on selenium concentrations and selenium species in forages across Oregon. Animal Feed Science and Technology 276: 114944.

Wang, M., R. Gao, M. Franco, **D.B. Hannaway**, W. Ke, Z. Ding, Z. Yu, X. Guo. 2021. Effect of Mixing Alfalfa with Whole-Plant Corn in Different Proportions on Fermentation Characteristics and Bacterial Community of Silage. Agriculture 11: 174-185. <https://doi.org/10.3390/agriculture11020174>

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Gultekin, Yunus, Shelby Filley, Mary Smallman, **David Hannaway, Serkan Ates**. 2020. Pasture production, persistence of legumes and lamb growth in summer-dry hill pastures. Grass and Forage Science. Article ID: GFS12497. DOI 10.1111/gfs.12497.

Qin, Ruijun, C. Noulas, D. Wysocki, X. Liang, **G. Wang** and S. Lukas. 2020. Application of plant growth regulators on soft white winter wheat under different nitrogen fertilizer scenarios in irrigated fields. MDPI-Agriculture. DOI: 10.3390/agriculture10070305.

Smith, R.W., M. Webb, D. Kidd and **D.B. Hannaway**. 2020. Mapping pasture species suitability using fine scale soils and climate data. Crop & Pasture Sci. 70 (12): 1175-1183. https://doi.org/10.1071/.

Tan, Shuhao, Weizhu Dai, Ruxin Zhang, and **David B. Hannaway**. 2020. Multi-household Grassland Management Pattern Promotes Ecological Efficiency of Livestock Production. Ecological Economics: 171. <https://doi.org/10.1016/j.ecolecon.2020.106618>

Wilson, Randi L., Massimo Bionaz, Jennifer W. MacAdam, Karen A. Beauchemin, Harley D. Naumann, and **Serkan Ates**. 2020. Milk production, nitrogen utilization, and methane emission of dairy cows grazing grass, forb, and legume-based pastures. Journal of Animal Science. <https://doi.org/10.1093/jas/skaa220>

Zhang, Ruxin, ShuhaoTan, **David Hannaway**, and Weizhu Dai. 2020. Multi-household grassland management pattern promotes ecological efficiency of livestock production. Ecological Economics 171 106618. <https://doi.org/10.1016/j.ecolecon.2020.106618>.

Zhu, Yajuan and **Guojie Wang**. 2020. Rainwater use process of Caragana intermedia in semi-arid zone, Tibetan Plateau. Frontiers in Earth Science-Hydrosphere. <https://doi.org/10.3389/feart.2020.00231>.

*Proceedings publication*

*Bulletins and Extension Factsheets*

Bohle, M. (2021) On-Farm Nitrogen Rates Effect on ‘Hoody’ Winter Barley Yield, Quality, Nutrient Concentration and Uptake at Lone Pine, Oregon in 1994. Central Oregon Ag Research and Extension Center 2020 Report. Oregon State University Pages: 47-53. <https://agsci.oregonstate.edu/sites/agscid7/files/assets/coarec_annual_report_2020_final.pdf>

Hannaway, and Forage-Livestock Systems Working Group. 2021. Oregon Forages. Web segment within Forage Information System. https:/forages.oregonstate.edu/Oregon (continuing development)

Brummer, Fara, Serkan Ates, David B. Hannaway, 2021. Birdsfoot Trefoil in Irrigated Pastures: Northern Great Basin Pasture Systems Can Benefit From Legume Interseeding. Oregon State Univ. Extension Ser. EM 9319. <https://catalog.extension.oregonstate.edu/em9319>

Fery, Melissa, David Hannaway, David Chaney, Maud Powell, and Garry Stephenson. 2020. Introduction to Pasture & Grazing Management. Oregon State University Extension Service Circular. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9302.pdf

Dreves, A., N. Kaur, M. Bohle, D. Hannaway, G. Fisher, and S. Rondon. 2020. Insect and Mite Pests of PNW Pastures. <https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw750.pdf>

**7. Scientific and Outreach Presentations**

Wang, Guojie and David B. Hannaway. 2021. Oregon Forage Projects. NCCC31 Virtual Annual Meeting. July 21-22.

Wang, Guojie, Mylen Bohle, Serkan Ates, and David B. Hannaway. 2021. Oregon Forage Projects. WERA 1014 Annual Meeting. Prosser, WA. July 27-28.

Carmona-Flores, L., M. Bionaz, T. Downing, M. Sahin, S. Ates. 2020. Effects of diversity and spatial separation of pastures on milk yields, N partitioning, and methane emissions in dairy cows. ADSA2020 Virtual Annual Meeting, June 24.

Ford, H., S. Busato, E. Trevisi, Y. Gultekin, M. Bionaz, and S. Ates. 2020. Chicory and plantain-dominated forb pasture improves health and rumen N efficiency in lactating dairy cows. ADSA2020 Virtual Annual Meeting. June 24.

Melathopoulos A.P. and S. Ates. 2020. Evaluating the nectar and pollen resources for honey bees in western Oregon non-irrigated pasture systems. 79th Annual Pacific Northwest Insect Management Conference. January 6-7. Portland, Oregon.

Wilson, R.L., M. Bionaz, J.W. MacAdam, K.A. Beauchemin, H.D. Naumann, and S. Ates. 2020. Milk production, nitrogen utilization, and methane emission of dairy cows grazing grass, forb, and legume-based pastures. ADSA2020 Virtual Annual Meeting. June 6.

8. Collaborative Grants

**Ates, S.,** Wang, G., and Brummer, F. 2021-2023. Overseeding novel forages in Oregon as a model for enhancing perennial grass pastures in the Pacific Northwest. USDA-WSARE.

**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.

Norberg, S., L. Yu, G. Zanton, G. Shewmaker, **G. Wang**, D. Llewellyn and S. Fransen. 2020. Determing genetic factors that influence protein quality and yield in alfalfa. USDA-NIFA.

**Wang, G**. 2020. Cover crops after forage spring triticale in eastern Oregon. Oregon State University Agricultural Research Foundation Grant.

**Wang, G**. 2020. Developing a fall-winter grazing system by using fodder beets. Oregon State University Agricultural Research Foundation Grant.

**Wang, G**. 2020. Irrigation and seeding date effects on winter grasses and forbs forage production and quality in eastern Oregon. Oregon Beef Council.

**Wang, G**. 2020. Long-term forage production of perennials effects on soil health under limited and competing water resources in eastern Oregon. Oregon State University Agricultural Research Foundation Grant.

**9. Graduate students**

Blair, Sally. 202X. Using annual forages to extend grazing season in early spring and late fall. Master of Science. Thesis. Oregon State University. G. Wang (Co-advisor)

Carmona, Flores, L. F. 2020. Effects of Diversity and Spatial Separation of Pastures on Forage Production, Milk Yields, N Partitioning and Methane Emissions. Master of Science Thesis. Oregon State University. S. Ates (Advisor) and G. Wang (Committee Member)

Gultekin, Yunus. 2020. Pasture Production and Lamb Growth from Dryland Hill Pastures in Western Oregon. Master of Science Thesis. Oregon State University. S, Ates (Advisor) and G. Wang (Committee Member)

Sahin, Elif. 2020. Breeding for Improved Forage Digestibility and Yield Potential in Tall Fescue. Master of Science Thesis. Oregon State University. D. Hannaway (Advisor)

Sahin, Muhammet. 2020. Selection for Persistence in Red Clover (Trifolium pratense L.) Through Improved Tolerance to Northern Anthracnose. Master of Science Thesis. Oregon State University. D. Hannaway (Advisor)

Wilson, R. L. 2020. Milk Production, Pasture Performance, and Environmental Sustainability of Specialized Pastures. Master of Science Thesis. Oregon State University. S. Ates (Advisor)

**Tennessee 2020-2021**

**University of Tennessee**

1. Impact Nugget  
The current forage research projects being conducted at the University of Tennessee includes 1) improvement of forage quality and nutritive value 2) sustainable forage management and production 3) mixed grass/legume swards to extend grazing season 4) incorporation of cover crops and living mulch into forage and cropping systems in the state of TN 5) organic forage production.

2. New Facilities and Equipment

* NIRs Foss DS2500 Instrument, Software Gas chromatograph
* C-Lock Smartfeeder

3. Unique Project Related Findings

* N/A

4. Accomplishment Summaries

Emergency seeding of cool-season annuals into perennial grass after fall drought. (Nave Oakes and Bates): Spring establishment of cool-season annual grasses into poorly producing orchardgrass (Dactylis glomerata L) (OG) swards may improve forage production and nutritive value in southeastern U.S following a fall drought. Annual ryegrass (Lolium multiflorum Lam.) (AR) and forage oats (Avena sativa L.) (FO) were seeded into an OG sward during two consecutive years in Middle Tennessee. An experiment was carried out with randomized complete block design consisting of two forage species combinations (OG+AR, OG+FO), three interseeding dates and the presence (+) or absence (-) of a burndown herbicide treatment (BD), as well as a control treatment of OG monoculture. In 2017, after a warm and wet winter, the OG was able to produce sufficient forage mass (FM) without significant reduction in nutritive value. Forage oats with BD treatment was more productive than AR, yet showed lower crude protein (CP) and higher fiber content. In 2018, OG had approximately 2600 lb ac-1 less FM than in 2017, suggesting that recurrent fall drought with unfavorable winter conditions resulted in long-term damage to the perennial sward. Meanwhile, treatments without BD did not show higher FM in the beginning of the season. Burndown treatment in general increased FM and nutritive value. Adequate productivity of drought-damaged OG swards is possible in the Mid-South by interseeding annual grass forages.

Forage species selection for transitional organic production. (Nave Oakes)  
Despite the vast production markets for forage and organic products nationally, limited work has been done to develop organic forage programs, especially for the Southeastern U.S. and similar regions globally. The present study seeks to evaluate several forage species and mixtures for optimizing forage production and nutritive value under low-input organic conditions. This study was conducted at the Middle Tennessee AgResearch and Education Center, in Spring Hill, TN, U.S. The forage treatments consisted of 1) monoculture tall fescue (Schedonorus arundinaceus (Schreb.) Dumort.), 2) monoculture bermudagrass (Cynodon dactlyon (L.) Pers.), 3) tall fescue and alfalfa (Medicago sativa L.) mixture, 4) bermudagrass and alfalfa mixture, and 5) an annual rotation of winter wheat [Triticum aestivum L.] mixed with winter pea [Pisum sativum L.] followed by sorghum-sudangrass [Sorghum bicolor (L.) Moench x S. sudanese (Piper) Stapf.] mixed with cowpea [Vigna unguiculata (L.) Walp.] mixture). Perennial treatments were established during the 2017-2018 growing season. Monthly production measurements occurred in the 2019 and 2020 growing seasons. Botanical composition fluctuated as a consequence of establishment dynamics and weed competition. Weed competition ranged from 200 to 800 g kg-1 in the perennial swards, and variably affected forage quantity and quality. Nutritive value was sufficient for most livestock operations across treatments, with average crude protein of all treatments remaining ~150 g kg-1 across two growing seasons. The annual rotation was the highest-yielding treatment, producing more than 6000 kg ha-1, though tall fescue and tall fescue-alfalfa produced (~4000 kg ha-1) without associated establishment concern. For transitioning organic producers, the annual rotation, tall fescue, or tall fescue mixed with alfalfa treatments might best serve their operations contingent on weed competition and establishment concerns.

Comparisons of alfalfa mix with tall fescue and bermudagrass on forage accumulation, botanical composition, and nutritive value. (Nave Oakes and Bates)

To utilize alfalfa (*Medicago sativa* L.), alone or in mixture with grasses, defoliation management practices must be evaluated to assess their performance. The objective was to determine forage accumulation (FA) and nutritive value of alfalfa monoculture (ALF) and in mixtures with tall fescue [ATF; *Lolium arundinaceum* (Schreb.) Darbyish)] or bermudagrass [ABG; *Cynodon dactylon* (L.) Pers] subjected to four harvest intervals (clipped every 21, 28, 35, and 42-d). The study was conducted in Crossville, TN and Charleston, OH during 2016 and 2017 growing seasons, and in Salisbury, NC during 2017 and 2018 growing seasons. Harvest intervals of 35-d or greater showed optimal FA, with greatest productivity in spring. In summer, the plot productivity of ATF was not different than ABG. The ATF mixture was superior to ABG in FA for the entire season. Although tall fescue can be very competitive with alfalfa in mixtures, it results in greater FA while reducing weed competition. Botanical composition indicated greater weed infestation in ALF than mixtures. Growing alfalfa-grass mixtures can increase sward CP compared with grass monocultures (average of 128 g kg-1 for ATF and 161 g kg-1 for ABG). We conclude that harvest intervals of 35-d or greater should be adopted to provide greater FA, and treatments ALF and ATF resulted in superior FA compared with ABG in the southern USA.

5. Impact Statements

6. Published Written Works

*Refereed publications*

1. Kubesch, J.O.C., **R.L.G. Nave**,A.P. Griffith, S. Cui, G.E. Bates, D.M. Butler, and V.R. Pantalone. 2021. Economic outcomes of cool and warm-season swards in transitioning organic swards. Agron. J. (in review).
2. Kubesch, J.O.C., **R.L.G. Nave**,S. Cui, G.E. Bates, D.M. Butler, and V. R. Pantalone. 2021. Forage species selections for transitional organic production in the Southeastern United States. Agron. J. (in review)
3. Xiong, Y.V., R.L.G. Nave, A.P. Griffith, M.P. Quinby, G.E. Bates, and M.D. Corbin. 2021. Emergency seeding of cool-season annuals into perennial grass after fall drought. Crop Forage and Turfgrass Management. (in review)
4. Quinby, M.P.; R.L.G. Nave; R.M. Sulc; M.S. Castillo; G. E. Bates; D. McIntosh; L. Schneider 2021. Comparison of alfalfa mixed with tall fescue and bermudagrass on forage accumulation, botanical composition, and nutritive value. Crop Sci. https://doi.org/10.1002/csc2.20461
5. Tilhou, N.W., **R.L.G. Nave,** S. Jagadamma, N. Eash, and J.T. Mulliniks. 2021. Forage species and summer management impacts on soil labile carbon and nitrogen in winter stockpiled grazing systems. Agrosystems, Geoscience and Environment. doi:10.1002/agg2.20132
6. Gelley, C.H., Ashworth, A., P. Keyser, **R.L.G. Nave**, and J. Rhinehart. 2020. Water-use efficiency of forage crops in the southeastern United States. Agronomy. doi:10.3390/agronomy10091377.
7. Quinby, M.P., **R.L.G. Nave**,G.E. Bates, and D. McIntosh. 2020. Harvest interval effects on the persistence and productivity of alfalfa grown as a monoculture or in mixtures in the southeastern United States. Crop Forage and Turfgrass Management. doi.org/10.1002/cft2.20018.
8. Barbero, R.P., E.B. Malheiros, N.M. Aguilar, E.P. Romanzini, A.C. Ferrari, **R.L.G. Nave**, J.T. Mulliniks, R.A. Reis. 2020. Supplementation level increasing dry matter intake of beef cattle grazing low herbage height. Journal of Applied Animal Research. doi.org/10.1080/09712119.2020.1715985.

*Proceedings publications*

None

*Book chapters*

**Nave,** **R.L.G.** and J. Tucker. 2020. Forage and Roughage Utilization/Grazing and Pasture Management. In: Modern Beef Production: Integrative approaches with nutrition, reproduction, and genetics. (in review)

Xu, S., S. Jagadamma, **R.L.G. Nave**, S. Cui, E. Byers, and Z. Li. 2020. Potential and Challenges of Growing Cover Crops in Organic Production Systems. In: Cover Crops and Sustainable Agriculture, The Ohio State University. (in press).

**Nave,** **R.L.G.** and D. Hancock. 2020. Forage Systems for Humid Transition Areas. In: 7th Edition of Forages, Volume II, The Science of Grassland Agriculture. ISBN: 978-1-119-43662-1.

7. Scientific and Outreach Presentations

*Abstracts , symposium and conference presentations*

1. Xu, S., Jagadamma, S., **R.L.G. Nave**, and S. Cui. 2020. Forage composition affected soil health in organic pasture systems. International Annual Meetings ASA-CSSA-SSSA – Virtual.
2. Kubesch, J., **R.L.G. Nave**, S. Cui, G. E. Bates, and D.M. Butler. 2020. Seeing the forage through the weeds: weed competition in transitioning organic systems. International Annual Meetings ASA-CSSA-SSSA – Virtual.
3. Xiong, Y., and **R.L.G. Nave**. 2020. Restoring cool-season pasture with alfalfa in efforts of forage mass, botanical composition, and nutritional value. International Annual Meetings ASA-CSSA-SSSA – Virtual.
4. Quinby, M.P., and **R.L.G. Nave**. 2020. Nitrogen requirements for corn production in white clover living mulch systems. International Annual Meetings ASA-CSSA-SSSA – Virtual.
5. Ferreira, G., and **R.L.G. Nave**. 2020. Estimating and comparing corn productivity in Brazil and United States. International Annual Meetings ASA-CSSA-SSSA – Virtual.
6. Quinby, M.P., **R.L.G. Nave**, and N. Hill. 2020. Corn silage and grain yield grown in living mulch systems. International Annual Meetings ASA-CSSA-SSSA – Virtual.
7. Kubesch, J., and **R.L.G. Nave**, S. Cui, A. Griffith, G. E. Bates, and D.M. Butler. 2020. Optimal forage species selection for southeastern transitional or low-input production. 2020 American Forage and Grassland Council Conference – Greenville/SC.

8. Collaborative Grants

**Nave, R.L.G.**, J.J. Tucker, G.E. Bates and A. Griffith. Restoring grasslands with the addition of alfalfa in an effort to sustainably increase alfalfa production in the Southeast. USDA-NIFA-Alfalfa Seed and Alfalfa Forage System Program. Sep 2019-Aug 2021. ($499,194)

**Nave, R.L.G.**, and G.E. Bates. Near Infrared Spectrometer – Foss DS2500 Instrument, Software, and Digital Services for Improved Accuracy of Forage Nutritive Value Analysis. University of Tennessee Research Instrument Grant. 2020. ($35,360)

McLean, K, P.R. Myer, J. D. Rhinehart, C. Boyer, G. Hao, **Nave, R.L.G.**, and R. Burns. Utilization of precision feeding to improve beef cattle development, reproduction, health, and performance via C-Lock Smartfeeder equipment. University of Tennessee Research Instrument Grant. 2020. (65,328)

Sykes, V., and **Nave, R.L.G.** 2021. Living mulch in organic corn systems. Tennessee Corn Promotion Board. Jan 2021 – Jan 2022. (30,000)

9. Graduate students

Y.V. Xiong, Post Doc. End date 2021. Restoring grasslands with the addition of alfalfa to sustainably increase alfalfa production in the Southeast.

M.D. Corbin. PhD. Expected graduation date 2022. Stockpiled tall fescue mixed with cool and warm-season legumes under grazing systems.

M.P. Quinby. PhD. Expected graduation date 2022. Corn grain and silage production under the white clover living mulch system.

K. Johnson, M.S. Expected graduation date 2023. Tall fescue and orchardgrass productivity and persistence under grazing systems in Tennessee.

**Texas 2020-2021**

**Texas A&M System Research Report**

1. **Impact Nugget**

Texas A&M AgriLife Research has improved the resource efficiency of forage production by developing summer dormant cool-season grasses, refining best management practices of novel and existing grasses and legumes, evaluating the impact of supplementation on grazing cattle, and furthering the understanding of the fundamentals of the water footprint when forages are integrated into agriculture systems.

1. **New Facilities and Equipment**

Nothing to report.

1. **Unique Project Related Findings**

Texas A&M AgriLife Research evaluated the nutritive value as impacted by management of forage sorghum and small grains, evaluated the potential for Teff, *Brachiaria*, or summer-dormant cool-season grasses to be incorporated into Texas forage systems. Recent forage sorghum silage research confirmed that harvest timing and management are critical to optimize forage sorghum silage quality and that sorghum crops that fail to produce grain can be ensiled for livestock feed. Determined the potential of cool-season legume hay cover crops or warm-season legume dual crops to secure soil and the impact on water footprint, determined the feasibility and effectiveness of incorporating co-products, such as distillers grains and lipid-extracted algae into agriculture systems, released native grass, legume and other herbaceous forb cultivars, and disseminated results to land owners.

1. **Accomplishment Summaries**

During 2019-2020, faculty from Texas A&M University, AgriLife Research and Extension (Bell, Foster, Kimura, Malinowski, Muir, Olson, Redmon, and Rouquette) published data on variety of basic forage-agronomy research topics. Outreach activities included the delivery of our findings during in-service training sessions, field days, and through various extension publications. Faculty at Texas A&M AgriLife Research, Texas A&M University-Kingsville, Texas Native Seed, Texas A&M University, and Tarleton State University continue the working group focused on domesticating and promoting native grassland grasses and forbs for wider use in rangeland revegetation, cultivated pasture, ornamental horticulture, wildlife habitat and feed, and bioenergy.

1. **Impact Statements**

Issue: Increasing dairy herds in Texas High Plains are increasing demands for annual silages beyond the existing demand from the beef cattle industry. Expanding droughts and decreasing irrigation capacities are affecting the quantity and quality of forage for silage that can be produced to meet the annual demand.

Action: Sorghum lines among BMR types are not equal in their nutritive value, recommendations on those which have the least lodging and greatest potential for sorghum silage were recommended to landowners.

Issue: Fallow periods in row-cropping agriculture leave the soil prone to erosion and reduced organic matter and water holding capacity.

Action: Cotton and sorghum production is not reduced by use of cool-season legume cover crops when incorporated into strip-till cotton-sorghum rotations, water footprint is still under long-term evaluation.

Issue: Improvement in livestock production can only occur by improvements to the quantity and quality of forages in the diet and our ability to measure or estimate these factors.

Action: We have generated data on relatively new warm-season annual forage, teff, for the forage producers in the Rolling Plains of Texas. Forage quality research led to the first published model that predicts forage nutritive value of bermudagrass pastures on a dynamic, daily basis. (Woli et al. 2021). Another ‘first-model’ includes modifications of TDN (total digestible nutrients) for bermudagrass and other warm-season perennial grasses (Woli et al. 2020). This will have direct application for commercial forage laboratory analyses. Research on the use of remote sensors for measures of forage quantity and botanical composition in combination with artificial intelligence analytics has resulted in improved accuracy of algorithms.

Issue: There are no perennial cool-season grasses which are adapted, and persistent in Texas.

Action: Texas A&M AgriLife has developed a summer-dormant tall fescue line TAL-02 that is being commercialized by Grasslands Innovation, NZ, and we are in the final stage of developing 2 cultivars of orchardgrass, and 2 cultivars of heat-tolerant hybrid perennial ryegrass.

Issue: There is a paucity of available native grassland commercial seed variety (species and ecotypes) for reseeding native pastures.

Action: Texas Native Seed (Texas A&M Kingsville) and Texas A&M AgriLife continue to collect native accessions of key grasses and forbs, evaluate for persistence and seed production and release the best germplasm for commercial applications in low-input pastures, rangeland rehabilitation, and native prairie restoration.

Contact:

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

[361-358-6390/jlfoster@ag.tamu.edu](mailto:361-358-6390/jlfoster@ag.tamu.edu)

Cooperators: Bell, Kimura, Malinowski, Muir, Olson, Redmon, and Rouquette

1. **Published Written Works**

*Book/Journal Issue*

Nothing to report.

*Book Chapters*

Nothing to report.

*Refereed Journal Articles*

* Acharya, M., Burke, J.M., J.E. Miller, T.H. Terrill, E.L. Wood, and J.P. Muir. 2020. Quebracho tannins aid in the control of Eimeria spp. and gastrointestinal nematodes in lambs and goat kids. Veterinary Parasitology 288: 109295. ttps://doi.org/10.1016/j.vetpar.2020.109295
* Acharya, M., Ashworth, A.J., Burner, D.M., Pote, D.H., Burke, J.M., and J.P. Muir. 2020. Browse potential of bristly locust, smooth sumac, and sericea lespedeza for small ruminants. Agroforestry Systems 94:1087-1098. doi:10.1007/s10457-019-00479-0
* Batista, L.F.D, M.E. Rivera, A.B. Norris, J.P. Muir, M.A. Fonseca, and L.O. Tedeschi.
* 2021. The Influence of Extended Supplementation of Quebracho Extract to Beef Steers Consuming a Hay Diet on Digestion, Ruminal, and Blood Parameters. Journal of Animal Science 99. https://doi.org/10.1093/jas/skab074
* Bell, J.M., E. Bynum, and P. Porter. 2020. Impact of sugarcane aphid on forage sorghum yield and silage nutritive value. Agro. J. 2021:1-19. <https://doi.org/10.1002/agj2.20751>
* Costa, C. dos S., M.C. Pinheiro Rogério, A. Lima Ferreira, A. L. Ferreira, F. Samarini Machado, R.C. Fernandes Franco Pompeu, F.G. da Silveira Alves, J.P. Arcelino do Rêgo, P. Guimarães Pimentel, J.P. Muir and J. N. Miranda Neiva. 2021. Dietary nutrient restrictions in the post-weaning period change Santa Inês ewe lamb nutritional metabolic profile. Tropical Animal Health Prod. 53:359. 10.1007/s11250-021-02767-3
* Costa, H. H. A., M.C. P. Rogerio, R.C.F.F. Pompeu, R.N. B. Lobo, A.R. Lima, C.S. Costa, E. S. Pereira, L. F. Gudes, and J. P. Muir. Evaluation of high-concentrate diets that vary in physically effective neutral detergent fibre for finishing lambs. South African J. Anim. Sci. 51(3):322. http://dx.doi.org/10.4314/sajas.v51i3.5
* Decunta, F.A., L.I. Pérez, D.P. Malinowski, M.A. Molina-Montenegro, and P.E. Gundel. 2021. A systematic review on the effects of Epichloë fungal endophytes on drought tolerance in cool-season grasses. Frontiers in Plant Science 12:644731. doi:10.3389/fpls.2021.644731/full
* Lockard, C.L., C.G. Lockard, W.N. Smith, K.J. Karr, B.P. Holland, A.B. Word, J.L. Foster, and J. S. Jennings. 2021. Effects of roughage type on particle separation, rumination, fiber mat characteristics, in situ degradation, and ruminal fermentation parameters in beef steers. J. Anim. Sci. (Accepted)
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*Symposium Proceedings*

Nothing to report.

*Abstracts*

Bagnall, D.K., S. Cappallazzi, G.M. Bean, M. Cope, D. Liptzin, K.L.H. Greub, E.L. Rieke, C.E. Norris, C.L.S. Morgan, C.W. Honeycutt, P.W. Tracy, and NAPSHM Collaborators. 2020. Management-sensitive pedotransfer functions for plant-available water holding capacity. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

- J.L. Foster authorship listed under NAPSHM Collaborators (North American Project to Evaluate Soil Health Measurements)

Bean, G.M., D.K. Bagnall, S.B. Cappellazzi, M. Cope, K.L.H. Greub, D. Liptzin, C.E. Norris, E.L. Rieke, P.W. Tracy, C.W. Honeycutt, C.L.S. Morgan, and Consortium of NAPESHM Partnering Scientists. 2020. Soil hydraulic properties as indicators of soil health: Measurement response to management and inherent soil properties. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

- J.L. Foster authorship listed under Consortium of NAPSHM Partnering Scientist (North American Project to Evaluate Soil Health Measurements)

Bekewe, P.E., H.L. Neely, C.B. Neely, J.L. Foster, K.L. Lewis, T.W. Boutton, B. Gerrish, and A.J. Gyawali. 2020. Comparing soil health parameters in no-till and conventional tillage farms across three ecoregions in Texas. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Burke, J.A., K.L. Lewis, and J.L. Foster. 2020. Moisture use, decomposition, and nutrient cycling of cover crops on Texas High Plains cotton production. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Burke, J.A., K.L. Lewis, and J.L. Foster. 2021. Nitrogen dynamics following cover crops in Texas High Plains cotton. Beltwide Cotton Conferences: Cotton Agronomy, Physiology & Soil Conference. Virtual Live-Stream, Jan. 5-7. (Abstr.)

Cappellazzi, S.B., E.L. Rieke, D. Liptzin, K.L.H. Greub, M. Cope, G.M. Bean, C.E. Norris, P.W. Tracy, C.L.S. Morgan, C.W. Honeycutt, and Consortium of NAPESHM Partnering Scientists. 2020. Comparing the usefulness of nitrogen measurements for use in soil health assessments. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

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Cardenas, S., A. Bhandari, A. Umphres, J.L. Foster, J. Landivar, and N. Dube. 2020. Response of high yielding cotton (Gossypium hirsutum L.) varieties to potassium fertilizer application in dryland South Texas. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Cooper-Norris, C.E., T. Zhang, J.P. Muir, D.B. Murray, K.E. Hood, A.B. Norris. 2021. *Nassella leucotricha* physiological responses to targeted grazing and microsite location. Proc. Society for Range Management.

Cope, M., G.M. Bean, S.B. Cappellazzi, K.L.H. Greub, D. Liptzin, C.E. Norris, E.L. Rieke, P.W. Tracy, C.W. Honeycutt, C.L.S. Morgan, and Consortium of NAPESHM Partnering Scientists. 2020. Towards quantitative ratings that reflect soil health principles: Soil tillage intensity. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

- J.L. Foster authorship listed under Consortium of NAPSHM Partnering Scientist (North American Project to Evaluate Soil Health Measurements)

Dube, N., A. Chang, X. Shen, J. Landivar, and J.L. Foster. 2020. Unmanned aircraft system (UAS) based forage biomass prediction using an artificial neural network. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Foster, J.L., P.E. Bekewe, H.L. Neely, C.B. Neely, L.E. Tomlin, A. Peyton Smith, A. Gyawali, and K.L. Lewis. 2021. Integrating conservation tillage and summer cropping into wheat production systems. 76th Soil and Water Conservation Society International Annual Conference, Virtual, Jul. 26-28. (Abstr.)

Garcia, A., G. Schuster, J.L. Foster, A. Umphres, and J. McGinty. 2020. Weed management systems in Imidazolinone tolerant grain sorghum. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Greub, K.L.H., K. Flynn, J.A. Howe, D.K. Bagnall, G.M. Bean, S.B. Cappellazzi, M. Cope, D. Liptzin, C.E. Norris, E.L. Rieke, P.W. Tracy, C.L.S. Morgan, C.W. Honeycutt, and Consortium of NAPESHM Partnering Scientists. 2020. Assessing the sensitivity and utility of aggregate stability methods for soil health evaluation. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

- J.L. Foster authorship listed under Consortium of NAPSHM Partnering Scientist (North American Project to Evaluate Soil Health Measurements)

Gyawali, A.J., A. Peyton Smith, H. Neely, R. Ghimire, J. Pintar, C. Neely, K. Lewis, and J.L. Foster. 2020. Assessing soil health in South Central United States. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Gyawali, A.J., J.L. Foster, H. Neely, P. Smith, P. Bekewe, C. Neely, K. Lewis, and J. Pintar. 2021. Soil health quantification and sampling. Soil Survey and Land Resource Workshop. Virtual, Feb. 4-5. (Abstr.)

Hines, A.R., B.C. Bellows, J.P. Muir, F.M. Rouquette, W.B. Smith. 2020. Nutrient Uptake by Warm-Season Forages from Manure from Steers Supplemented with Titrated Levels of Dried Distillers Grains. ASA-CSSA-SSSA International Annual Meeting. November, 2020. https://scisoc.confex.com/scisoc/2020am/prelim.cgi/Paper/131368

Hines, A.R., B.C. Bellows, J.P. Muir, F.M. Rouquette, W.B. Smith. 2020. Nutrient Uptake by Cool-Season Forages from Manure from Steers Supplemented with Titrated Levels of Dried Distillers Grains. ASA-CSSA-SSSA International Annual Meeting. November, 2020. https://scisoc.confex.com/scisoc/2020am/prelim.cgi/Paper/131367

Howell, K.N., J.P. Muir, D.B. Murray, A.B. Mitchell, and J.R. Bow. 2020. Texas Little Bluestem (*Schizachyrium scoparium*) Phenotypic Attribute Correlations to Collection Site Environment Characteristics. Botanical Research Institute of Texas Annual Meeting proceedings. August 3, 2020. First Place Graduate Student competition.

Howell, K., J.P. Muir, D. Murray. 2020. Texas Little Bluestem (*Schizachyrium scoparium*) Phenotypic Attribute Correlations to Collection Site Environment Characteristics. ASA-CSSA-SSSA International Annual Meeting. November, 2020. https://scisoc.confex.com/scisoc/2020am/prelim.cgi/Paper/126633

Liptzin, D., G.M. Bean, S.B. Cappellazzi, M. Cope, K.L.H. Greub, C.E. Norris, E.L. Rieke, P.W. Tracy, C.W. Honeycutt, C.L.S. Morgan, and Consortium of NAPESHM Partnering Scientists. 2020. Carbon indicators of soil health: Relationships among indicators and the role of management and intrinsic factors. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

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Malinowski, D.P., Pinchak, W.E., and J. Ford. 2020. Heat, drought stress and dormancy for grasses in southern latitudes. ASA-CSSA-SSSA International Annual Meeting – Virtual. 19-13 November 2020. Madison, WI.

Muir, J.P., C.J. Dubeux, Jr., M.V. Ferreira dos Santos, G.M. Fagundes, C.H. Espirito Candal Poli, and L.O. Tedeschi. 2021. Deciphering condensed tannin and ruminant interactions from the plant’s perspective. ASA-CSSA-SSSA International Annual Meeting Salt Lake City, UT. November, 2021.

Pintar, J., A.J. Gyawali, A.P. Smith, H. Neely, J.L. Foster, and P. Bekewe. 2020. Developing spatial sampling strategies for monitoring microbial exoenzyme activity for soil health. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Rieke, E.L., G.M. Bean, S.B. Cappellazzi, M. Cope, K.L.H. Greub, C.E. Norris, D. Liptzin, P.W. Tracy, C.W. Honeycutt, C.L.S. Morgan, and Consortium of NAPESHM Partnering Scientists. 2020. Assessment of targeted amplicon sequencing as an indicator of soil health. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

- J.L. Foster authorship listed under Consortium of NAPSHM Partnering Scientist (North American Project to Evaluate Soil Health Measurements)

Shen, X, J. Landivar, A. Chang, N. Dube, and J.L. Foster. 2020. Identifying botanical composition and accuracy assessment on high-resolution imagery of grassland mixtures. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

Shen, X., A. Chang, N. Dube, J.A. Landivar, R.W. Jessup, M.J. Starek, M.K. Clayton, and J.L. Foster. 2021. Identifying botanical composition and accuracy assessment from Unoccupied Aircraft System (UAS) imagery for grassland mixture. ASPRS The Imaging and Geospatial Information Society Annual Conference. Virtual, Mar. 29-Apr. 2. (Abstr.)

Tedeschi, L.O., A.B. Norris, H.D. Naumann, C.A. Ramirez-Restrepo, and J.P. Muir, 2021. Plant condensed tannin influences on rumen methanogenesis and undegradable protein 133306. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City UT. November, 2021.

Tolleson, D.R., F.M. Rouquette, K.D. Norman, and C.R. Long. 2021. Effect of stocking rate during gestation on subsequent performance of growing beef cattle. J Anim Sci. Louisville, KY.

Tracy, P.W., D.K. Bagnall, G.M. Bean, S. Cappellazzi, M. Cope, K.L.H. Greub, D. Liptzin, C.W. Honeycutt, C.L.S. Morgan, C.E. Norris, E.L. Rieke, and Consortium of NAPESHM Partnering Scientists. 2020. Comparing soil carbon measurements from long-term agricultural experiments across the United States with comet-farm estimations. ASA-CSSA-SSSA 2020 International Meetings, Virtual, Nov. 8-11. (Abstr.)

- J.L. Foster authorship listed under Consortium of NAPESHM Partnering Scientist (North American Project to Evaluate Soil Health Measurements)

Valencia, E., A. Lema Solis, J.P. Muir. 2020. Tropic Sun-Pearl Millet Mixtures Affect Yield and Nutritive Value. ASA-CSSA-SSSA International Annual Meeting. November, 2020. https://scisoc.confex.com/scisoc/2020am/prelim.cgi/Paper/131766

Valencia, E., A. Lema, J.P. Muir. 2020. Cowpea (*Vigna unguiculata* (L.) Walp.) Potential as a Forage Crop at Flowering and Seed Filling Stage. ASA-CSSA-SSSA International Annual Meeting. November, 2020. https://scisoc.confex.com/scisoc/2020am/prelim.cgi/Paper/131753

Victoria, M., H.R. Leggette, J.L. Foster, H. Neely, C. Neely, J. Lofton, J. Copes, K.L. Lewis, P. Bekewe, and A. Gyawali. 2021. Adopt what? Describing Louisiana wheat producers’ level of adoption of soil health management practices. 76th Soil and Water Conservation Society International Annual Conference, Virtual, Jul. 26-28. (Abstr.)

Victoria, M., H.R. Leggette, J.L. Foster, H. Neely, C. Neely, J. Lofton, J. Copes, K.L. Lewis, P. Bekewe, and A. Gyawali. 2021. Promoting soil sustainability in Texas Oklahoma, and Louisiana through communication and education. American Association for Agricultural Education National Conference, Virtual, May 24-27. (Abstr.)

Victoria, M., Leggette, H.R., Foster, J.L., Neely, H., Neely, C., Lofton, J., Lofton, J., Lewis, K., Parvej, R., Bekewe, P., and Gyawali, A. 2021 Soil health management adoption by wheat producers in the south-central United States. Southern Family Farmers & Food Systems Conference, Texas State University, San Marcos, TX, Aug. 9-10. (Abstr.)

*Extension Publications*

Bell, J.M., C. Naylor, K. Heflin, P. Sirmon, N. Porter, R. Schnell, and K. Horn. 2020 Texas A&M AgriLife Bushland Forage Sorghum Silage Trial. SCS-2021-7 https://amarillo.tamu.edu/files/2020/12/2020-AgriLife-Forage-Sorghum-Silage-Trial.pdf

Corriher-Olson, V., and J. Banta. 2020 Herbicide and Insecticide Cost Per Acre Spreadsheet. SCS-2019-03.

McGinty, J., V. Corriher-Olson, M. Clayton and R. Lyons. 2020. Quick Reference for Common Rangeland and Pasture Herbicides. ESC-046.

Rouquette, Jr., Monte. 2020. Selection of calving season: Matching forages, pastures, and stocking strategies. Res. Center Tech. Rept. 2020-1.

Rouquette, Jr., Monte and Kelli Norman. 2020. Weaning weights from fall and winter calving seasons: Influence of stocking rates on pasture. Res. Center Tech. Rept. 2020-2.

Smith, G.R. and F.M. Rouquette, Jr. 2020. Winter pasture establishment in warm-season perennial grass pastures. Res Center Tech Rept. 2020-3.

Rouquette, Jr., Monte. 2020. Virtual perspectives of management strategies for pastures and beef cattle: What to look for. Res. Center Tech. Rept. 2020-4.

Rouquette, Jr., Monte. 2021. Forages, pastures, and management options for pasture-finished beef. Res. Center Tech Rept. 2021-1

*Popular Articles*

Corriher-Olson, V. 2020. Avoiding Confrontation. CSA News. Vol. 65, Issue 4. March 20, 2020.

Corriher-Olson, V. 2020. Emotional Intelligence. CSA News. Vol. 65, Issue 6. May 20, 2020.

Fears, R. Wheatlage Becoming Popular in the Texas High Plains. Progressive Forage. 12/1/2020 https://www.progressiveforage.com/forage-types/other-forage/wheatlage-becoming-popular-in-the-texas-high-plains

Guillen-Portal, F., R. Garetson, C. Neely, B. Gerrish, R. Noland, E. Kimura, J. Bell, J.H. Ramirez, M. Berry, J. Klinksiek, and T. Bell. 2020. Texas cool-season forage variety trial results. Texas A&M AgriLife Extension. SCS-2020-10.

Hugeley, S. Forage sorghum trials aim to resolve production questions. Southwest FarmPress. 8/24/2020 https://www.farmprogress.com/sorghum/forage-sorghum-silage-trials-aim-resolve-production-questions

Hugeley, S. Agronomist Jourdan Bell gives Wheatlage production tips. Southwest FarmPress. 8/22/2020 https://www.farmprogress.com/wheat/agronomist-jourdan-bell-gives-wheatlage-production-tips

Hugeley, S. September cold front causes premature defoliation in dryland cotton. Southwest FarmPress. 8/22/2020 https://www.farmprogress.com/cotton/september-cold-front-causes-premature-defoliation-dryland-cotton

Hugeley, S. Corn: Optimizing yields, minimizing risks with limited irrigation. Southwest FarmPress. 12/3/2020 https://www.farmprogress.com/corn/corn-optimizing-yields-minimizing-risks-limited-irrigation

Ledbetter, K. and J. Bell. Weather negatively impacts forage sorghum silage trial. AgriLife Today. 1/12/2020 https://agrilifetoday.tamu.edu/2021/01/11/weather-negatively-impacts-annual-forage-sorghum-silage-trial/

Ledbetter, K. and V. Corriher-Olson. 2020. Understanding Introduced Pasture Fertilization Webinar set June 7. The Eagle.

Newlin, L. Texas A&M Agronomist highlights wheat silage. High Plains Journal. 8/18/2020 https://www.hpj.com/crops/texas-a-m-agronomist-highlights-wheat-silage/article\_0654d9a2-e02f-11ea-a898-735cabb56ea6.html

Russell, Adam and V. Corriher-Olson. 2020. Pesticide Applicator Online Program Set Dec. 3. AgriLife Today.

Russell, Adam and V.Corriher-Olson. 2021. Hay Producing Areas Report Below-Average Season. AgriLife Today.

Russell, Adam and V. Corriher-Olson. 2021. Managing Pasture Hay Insect Pests Program Set Aug. 18. AgriLife Today.

**Scientific Outreach Presentations**

Bell. J.M. 2021. Weed Control in Corn and Sorghum Forages. NMSU Forages Online Workshops 4/7/2021 Invited https://ezregister.com/events/34286/

Bell. J.M. 2021. Managing Sugarcane Aphids in Sorghum Silage to Optimize Yield and Nutritive Value. The 2021 Annual University of Arizona Alfalfa & Forage Workshop – Virtual. 4/8/2021 Invited

Bell, J.M. 2021. Planting considerations for short-season environments. 2nd Great Plains Cotton Conference – Virtual. 2/23/2021 Invited

Bell, J.M. 2020. The Impacts of Dry Weather and Limited Water on Silage Production

Session 1: Silage for Beef Cattle. University of Nebraska and Iowa State. Silage for Beef Cattle Virtual Conference Webinar Series. 6/7/2020 Invited

Bell, J.M. 2020. Water and Sugarcane Aphid Stress on Sorghum Silage Quality. University of Arizona Extension: 6th Annual Alfalfa and Forage Crops Workshop. 3/26/2020 Invited

Bell, J.M. 2020. Forage Sorghum vs. Corn Silage: Effects of Water Stress on Silage Quality. 2020 High Plains Dairy Conference (NMSU & AgriLife Extension): Round-robin: Water & Cropping Outlook, What’s New? 3/3/2020 Invited

Foster, J.L. Remote Sensing Applications for Grasslands. Texas A&M University-Kingsville Summer Research Programs Webinar Series. Virtual Event, Aug. 5, 2021.

Foster, J.L. Lessons from Long-term Tillage and Cover Crop Studies in the Coastal Bend. Farming in a Carbon Economy. Texas A&M AgriLife Extension of Nueces and San Patricio Counties, Virtual Event, May 11, 2021.

Foster, J.L. Selection and Management of Introduced and Native Grasses. Mid-Coast Beef and Forage Seminar. Texas A&M AgriLife Extension Calhoun County Continuing Education Unit Event. May 7, 2021.

Foster, J.L. Agronomy and Plant Sciences. Metro Elementary School Family Science Night, Virtual Event for school in Corpus Christi, TX, Feb. 25, 2021.Foster, J.L. Texas A&M Beef Cattle Short Course. Carbon Capture in Grazinglands. College Station, TX. Aug. 1-3, 2021.

Lewis, K.L., J. Bell, P. DeLaune, J.L. Foster, M. Maeda, and J. McGinty. Soil Health in Texas: Lessons from Long-Term Study Sites. Soil Health Institute Healthy Soils for Sustainable Cotton. Cotton Farmer Showcase. Virtual. Feb. 9, 2021.

Olson, V.C. East Texas Pasture Management Program. Weed Control in Pastures & Hay Meadows. Virtual. Feb. 19, 2021.

Olson, V.C. Blackland Income Growth. Baleage: What is it, when to use it, and can it fit my operation? Virtual. Jan. 5, 2021.

1. **Collaborative Grants between Stations and Members Awarded in 2019-2020**

Muir, J.P. et al. USDA-NRCS-CPPE. 2021. Integrating field, lab, and decision support tools for practical guidelines on manure application to cropland and pasture that enhance environmental and public health decision-making. AgriLife co-PI with Kan as PI. Total awarded: $????.

Muir, J.P. et al. USDA-NIFA-NLGCA. 2021. Developing Capacity for International Research in Human-Wildlife Conflicts in Agricultural Systems. AgriLife Co-PI with Schwertner at Tarleton. Total awarded: $750,000.

Muir, J.P. et al. Texas Corn Producer’s Board. 2021. Hi-A Corn as a Dairy Feed for Rumen-Protein Bypass, Lower Methane Emissions, Potential Animal Health Benefits and Increased Environmental Sustainability. (PI). Total awarded: $61,000.

Muir, J.P., J.L. Foster, et al. USDA/DOE South-central SUN. 2021-2023. Novel perennial native grasses for sustainable multiple uses: Bioenergy, CRP, wildlife & forages. Muir PIat AgriLife. Total awarded: $342,000.

Muir, J.P. et al. Conservation Innovation Grant, NRCS. 2021-2023. Biocarbon-Enhanced Dairy Manure Management Demonstration for Enhanced Water Quality. Co-PI at AgriLife with Kan as PI at AgriLife. Total awarded: $735,239

1. **Graduate Students**

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

*Foster*

Shen, Xiaoqing. PhD. 2022. Application of Botanical Composition Identification and Accuracy Assessment for Grassland Mixtures and Brush from Unoccupied Aircraft System (UAS) Imagery.

1. **Other**

*Disclosures of Forage Cultivars for Release as Variety*

Smith, G.R. and F.M. Rouquette, Jr. 2020. Rio Verde Forage Lablab Bean. Disclosure 2482AGLR07. Evaluation contract with Green Cover Seed, Bladen, Nebraska (3-31-2020; L-001625).

**Utah Report 2020-2021**

**Utah State University**

1. Impact Nugget:

2. New Facilities and Equipment:

None

3. Unique Project Related Findings:

4. Impact Statements and Accomplishments

5. Published Written Works

***Improving forage and bioenergy crops for better adaptation, resilience, and******flexibility***(Hatch 2019-2022). Earl Creech. Selection of late-heading orchardgrass to improve yield and nutritive value in grass-alfalfa mixtures; the use of companion seeding oats as an aid to alfalfa establishment; evaluation of management practices to avoid injury from freezing temperatures to glyphosate-resistant alfalfa; evaluation of the performance of dairy cattle breeds on various pasture grasses (tall fescue, orchardgrass, meadow brome, and perennial ryegrass) grown in mixtures with birdsfoot trefoil. Multi-year trials of reduced lignin alfalfa were completed, and new variety trials of alfalfa and timothy were established including a 43-entry alfalfa trial on a saline location.

***Economic and environmental sustainability of heifer development strategies in pasture-based organic dairy systems*** (NIFA Grant 2017-51300-26866; 2017-2021 for $999,404). Isom, S. C.; Miller, RH, L.; Young, AL, J..; Peel, MI, .; Waldron, BL, .; Creech, J., EA.; Rood, KE, .; Feuz, DI, M.; Heleba, DE, .; and Thornton-Kurth, KA. Treatments were tall fescue, meadow bromegrass, orchardgrass, and high-carbohydrate perennial ryegrass planted in pastures as monocultures and mixtures with birdsfoot trefoil and rotationally grazed by peri-pubertal Jersey heifers. Factors to be determined include forage production and dry matter intake (BFT mixtures had greater herbage intake than grass monocultures in the order MB+BFT, OG+BFT, OG, MB, PR+BFT, TF+BFT, PR, TF). Heifers grazing grass-BFT mixture pastures had better growth and development compared to heifers grazing grass monocultures. Mixed pastures with BFT may be a sustainable alternative to feeding a TMR for adequate growth of dairy heifers. The economic evaluation has not been completed and one Extension fact sheet has been published and the project has a presence on eOrganic.

***Employing forage legumes to improve the sustainability of ruminant production*** (Hatch 2017-2022). Jennifer MacAdam. 1. In a column study of two legumes, a grass and a non-legume forb that was carried out in the greenhouse through 10 harvests, equivalent to approximately three years of field growth, we demonstrated that the two legumes reduced total soil nitrogen concentration while the grass and forb increased total soil nitrogen. This was due to a far greater investment in roots by the grass and the forb. 2. In a study of long-chain fatty acids from four beef diets (two legume pastures, a grass pasture and a feedlot concentrate diet, we demonstrated that the subcutaneous fat of cattle grazing one of the legumes, birdsfoot trefoil, had elevated omega-3 fatty acid concentration relative to cattle on the feedlot diets or the other pasture diets. Grass pastures resulted in the greatest ratio of acetic to propionic acid (A:P), followed by birdsfoot trefoil pastures, with the lowest A:P in cattle fed a feedlot diet. A greater A:P is associated with reduced methane emissions. 3. In a field study of alfalfa and meadow bromegrass, it was demonstrated that alfalfa accumulates between 35 and 45% of dry matter as non-fiber carbohydrate, including 25% of dry matter as pectins, while pectins comprise about 7% of grass dry matter.

***Management and environmental factors affecting nitrogen cycling and use efficiency in forage-based livestock production systems*** (Hatch 2019-2024). Rhonda Miller. Treatments were tall fescue, meadow bromegrass, orchardgrass, and high-carbohydrate perennial ryegrass planted in pastures as monocultures and mixtures with birdsfoot trefoil and rotationally grazed by Jersey heifers. The dairy impact of pasture production on nitrogen cycling in response to grazing grass-legume mixtures will be evaluated. Soil samples from 2016-2018 have been analyzed for nitrate, ammonia, and phosphorus. All leachate samples have been analyzed from 2016, 2017 and 2018 for nitrate. Urine samples have been analyzed for urea for all three years. Fecal samples have been run for total nitrogen and total carbon for all three years, but still need to be analyzed for ammonia.

***Chemical diversity in rangelands and pasturelands: a sustainable tool to enhance livestock production and ecological health while minimizing environmental impacts*** (Hatch 2017-2022). Juan Villalba. The invasive weed medusahead (*Taeniatherum caput-medusae* (L.) Nevski) was managed by grazing and herbicide applications, and intake of and preference for medusahead treated with glyphosate by livestock was evaluated, as well as the influence of the potassium salt present in glyphosate on selection of this grass. Non-treated medusahead was consumed to a greater extent than glyphosate-treated medusahead by lambs (P < 0.05) but in a two-way choice, all lambs tended to consume more medusahead treated at a high rate of glyphosate (P = 0.052). In a study with angus-cross steers of medusahead-infested pastures, medusahead defoliation declined to a greater extent in the glyphosate-treated plots than in the rest of the treatments (P = 0.022). Only small improvements in nutritional composition (reduced fiber contents and increased fiber digestibility) were observed in glyphosate-treated medusahead relative to the control. Both sheep and cattle showed increments in the use of medusahead. A combined herbicide-grazing treatment shows promise as a practical tool to reduce medusahead. In another study, pairs of heifers grazed 7 treatments: monocultures of birdsfoot trefoil, sainfoin and alalfa and all possible 2- and 3-way choices among strips of these legumes during two 15-d periods in 2 consecutive years. Average daily gains of heifers grazing tanniferous legumes (1.05 kg/d) were 40% greater (p b 0.10) than that of heifers grazing alfalfa during the first year. Heifers grazing the 3-way choice had greater intakes and gain than those grazing legume monocultures, suggesting a nutritional synergism among legumes. The average methane emissions for legume monocultures was greater than for 2- and 3-way choices. For heifers grazing sainfoin and birdsfoot trefoil compared with alfalfa, blood urea N was less but fecal N concentrations were. Combining the two tanniferous legumes (sainfoin and birdsfoot trefoil) led to the greatest declines in urinary N and urea-N concentrations, suggesting that different types of tannins in different legumes result in associative effects that enhance N economy. Heifers grazing 3-way choice treatments partitioned less N into urine and retained more N than heifers grazing legume monocultures. Heifers grazing the 3-way choice gained more BW than the average gains observed for animals grazing in all legume monocultures or 2-way choices, suggesting a synergism among pasture species for the treatment with the highest diversity. Spatial segregation of forage species into patches has the potential to enhance animal performance without influencing foraging behavior. The incorporation of a diverse array of chemicals into the diet, like the ingestion of different types and concentrations of condensed tannins or soluble carbohydrates may promote synergisms that benefit animal nutrition and health.

**Refereed Journal Articles**

Bateman, T. M., Villalba, J., Ramsey, R., and Sant, E. D. (2020). A multi-scale approach to predict the fractional cover of medusahead (*Taeniatherum caput-medusae*). Rangeland Ecology and Management, 73, 538-546.

Clemensen, A. K., Villalba, J., Rottinghaus, G. E., Lee, S. T., Provenza, F. D., and Reeve, J. (2020). Do plant secondary metabolite-containing forages influence soil processes in pasture systems? Agronomy Journal, 112, 3744-3757.

Distel, R. A., Arroquy, J. I., Lagrange, S., and Villalba, J. (2020). Designing diverse agricultural pastures for improving ruminant production systems. Frontiers in Sustainable Food Systems, 4.

Lagrange, S., Beauchemin, K. A., MacAdam, J. W., and Villalba, J. (2020). Grazing diverse combinations of tanniferous and non-tanniferous legumes: Implications for beef cattle performance and environmental impact. Science of the Total Environment, 746, 140788.

Lira, R., MacAdam, J. W., Sales, F., and Villalba, J. (2020). Supplementation strategies to enhance intake of romerillo (*Chiliotrichum diffusum*) by sheep in southern Patagonia. Small Ruminant Research, 192.

Lira, R., MacAdam, J. W., Sales, F., and Villalba, J. (2020). Supplemental levels of protein and energy influence ingestion of Romerillo (*Chiliotrichum diffusum*) by sheep in southern Patagonia. Small Ruminant Research, 191

Pedernera, M., Mereu, A., Cromer, E., and Villalba, J. (2020). Preference for inorganic sources of calcium and phosphorus by sheep as a function of need. Animal Science Journal, 91, e13460.

Pound, C., Yost, M., Creech, J. E., Cardon, G., Gale, J. A., Heaton, K., Price, S., Kitchen, B. M., Wilde, T., and Pace, M. (2020). Nitrogen fertilizer needs of first-year small grain forages following alfalfa. Agronomy Journal 113, 2006-2017.

Silva, J. A., Poli, C. H., Tontini, J. F., Irigoyen, L. R., Modesto, E. C., and Villalba, J. (2020). Ingestive behavior of young lambs on contrasting tropical grass sward heights. Frontiers in Veterinary Science, 7, 643.

Spackman, C. N., Monaco, T. A., Stonecipher, C. A., and Villalba, J. (2020). Plant silicon as a factor in medusahead (*Taeniatherum caput-medusae*) invasion. Invasive Plant Science and Management, 13, 143-154.

Waldron, B., Bingham, T., Creech, J. E., Peel, M., Miller, R. L., Jensen, K., Zobell, D., Eun, J.-S., Heaton, K., and Snyder, D. L. (2020). Binary mixtures of alfalfa and birdsfoot trefoil with tall fescue: herbage traits associated with the improved growth performance of beef steers. Grassland Science, 66, 74-87.

Waldron, B., Sagers, J., Peel, M., Rigby, C., Bugbee, B. G., and Creech, J. E. (2020). Salinity reduces the forage quality of forage kochia: a halophytic Chenopodiaceae shrub. Rangeland Ecology and Management, 73, 384-393.

Wilson, R.L., Bionaz, M., MacAdam, J. W., Beauchemin, K.A., Naumann, H.D., and Ates, S. (2020). Milk production, nitrogen utilization, and methane emission of dairy cows grazing grass, forb, and legume-based pastures. Journal of Animal Science 98 skaa220.

Zhang, Y., MacAdam, J. W., Villalba, J., and Dai, X. (2020). Nutritive value and plant secondary compounds influence forage in vitro digestibility. Journal of the Science of Food and Agriculture 101:334-340.

**Refereed Extension Publications**

Creech, J. E., Yost, M., Cardon, G., Ransom, C., and Clark, J. (2020). Considerations for crop rotation from alfalfa to corn. USU Extension.

Yost, M., Allen, L., Creech, J. E., Putnam, D. H., Gale, J. A., and Shewmaker, G. (2020). Ten reasons why alfalfa is highly suitable for the West. USU Extension.

Yost, M., Cardon, G., Allen, L., Sorenson, B., Egbert, K., Creech, J. E., Ransom, C., and Ramirez, R. (2020). Chemigation guide. USU Extension

Yost, M., Powell, C., Creech, J. E., Cardon, G., Gale, J. A., Pace, M., Kitchen, B. M., Price, S., Heaton, K., Nelson, R. M., Wilde, T., and Russell, K. (2020). Nitrogen Fertilizer Guide for First-Year Small Grains Following Alfalfa. USU Extension

**Book Chapters**

Allen, L., and MacAdam, J. W. (2020). Irrigation and water management. pp. 497-513 *In* M. Collins, C.J. Nelson, K.J. Moore, and D. Redfearn (ed.) Forages, Vol. II: The Science of Grassland Agriculture, 7th Ed., Wiley Blackwell, Hoboken, NJ.

MacAdam, J. W., and Nelson, C.J. (2020). Plant-water relations in forage crops. pp. 113-126 *In* M. Collins, C.J. Nelson, K.J. Moore, and D. Redfearn (ed.) Forages, Vol. II: The Science of Grassland Agriculture, 7th Ed., Wiley Blackwell, Hoboken, NJ.

**Proceedings**

Creech, J. E., Loveland, C., Yost, M., Ransom, C., and Putnam, D. (2020). How to avoid glyphosate injury in glyphosate-resistant alfalfa. (vol. 73, pp. 72). Proceedings of the Western Society of Weed Science.

**Presentations**

Burgos-González, C., Villalba, J., Vázquez, R., and Pedernera, M., 2020. Free-choice diet selection by sheep during peripartum. American Society of Animal Science (ASAS) - Canadian Society of Animal Science (CSAS), Virtual Meeting. (July 19, 2020 - July 23, 2020)

Clemensen, A., Villalba, J., Rottinghaus, G., Lee, S. T., and Provenza, F. D., 2020. Do plant secondary metabolite-containing forages influence soil dynamics in pasture systems?, Society for Range Management, Denver, CO. (February 16, 2020 - February 20, 2020)

Getz, M., and Creech, J. E. (2020). Targeting late flowering time and forage quality association study within a segregating orchardgrass population. Western Society of Crop Science Annual Meeting.

Lagrange, S. P., MacAdam, J. W., and Villalba, J., 2020. Grazing diverse combination of tanniferous and non-tanniferous legumes: implications for foraging behavior, performance and hair cortisol in beef cattle, American Society of Animal Science (ASAS) - Canadian Society of Animal Science (CSAS), Virtual Meeting. (July 19, 2020 - July 23, 2020)

Lira, R., MacAdam, J. W., Sales, F., and Villalba, J. 2020. Supplementation strategies to enhance intake of romerillo (Chiliotrichum diffusum) by sheep in southern Patagonia, Society for Range Management, Denver, CO. (February 16, 2020 - February 20, 2020)

Miller, R. L., Long, J., Waldron, B., Isom, S., Rood, K., Creech, J. E., Peel, M., Briscoe, J., Rose, M., and Hadfield, J. (2020). Impacts of grass-legume mixtures versus monocultures on nitrogen cycling in an organic dairy grazing system. Washington State University: Pacific and Mountain West Nutrient Cycling, Soil Health and Food Safety Virtual Conference.

Miller, R. L., Long, J., Waldron, B., Isom, S., Rood, K., Creech, J. E., Peel, M., Briscoe, J., Rose, M., and Hadfield, J. (2020). Improving organic grazing systems. Washington State University: Pacific and Mountain West Nutrient Cycling, Soil Health and Food Safety Virtual Conference.

Pedernera, M., Vulliez, A., and Villalba, J., 2020. The influence of prior experience on dietary diversity in sheep, American Society of Animal Science (ASAS) - Canadian Society of Animal Science (CSAS), Virtual Meeting. (July 19, 2020 - July 23, 2020)

Roberts, C., Yost, M., Ransom, C., and Creech, J. E. (2020). The impacts of irrigation, herbicide, and oat companion crop on spring-seed alfalfa. Western Society of Crop Science annual meeting.

Spackman, C., Monaco, T., and Villalba, J. 2020. Medusahead silicon, constraining factors of control, and research needs, Society for Range Management, Denver, CO. (February 16, 2020 - February 20, 2020)

Spackman, C., Cooper, A., and Villalba, J. 2020. Society for Range Management Annual Meeting,, "Timing of Glyphosate Application to Increase Cattle Consumption of Medusahead," Society for Range Management, Denver, CO. (February 16, 2020 - February 20, 2020)

**Theses and Dissertations**

Bolletta, A. I. (MacAdam, J.W., advisor). 2020. *Enhancing the production and sustainability of pasture-fed beef using non-traditional legume forages*. Doctoral Dissertation, Utah State University, Logan, Utah.

Lagrange, S. P. (Villalba, J.J., advisor). 2020. *Influence of forage diversity and condensed tannins on livestock foraging behavior, production and environmental impact*. Doctoral Dissertation, Utah State University, Logan, Utah.

Loveland, C. (Creech, J. E., advisor). 2020. *Response of glyphosate-resistant alfalfa to glyphosate application in the Intermountain West*. Master’s Thesis. Utah State University, Logan, Utah.

Pound, C. (Yost, M., advisor). 2020. *Nitrogen fertilizer needs of first-year small grains following alfalfa*. Master’s Thesis. Utah State University, Logan, Utah.

Rose, M. (Creech, J. E., advisor). 2020. *Pasture Management to Improve Dry Matter Intake*. Master’s Thesis. Utah State University, Logan, Utah.

Slebodnik, K.A. (Reeve, J.R., advisor). 2020. *Effect of plant-derived tannins on nitrogen and carbon cycling in pasture soils*. Master’s Thesis. Utah State University, Logan, Utah.

**Popular Press**

MacAdam, J. W., and Yost, M. (2020). Mountain Hay. Progressive Forage, Issue 2, February 1, 2020.

**Wisconsin Report 2020-2021**

**University of Wisconsin**

Impact Nugget

The forages and perennial grains program at UW-Madison consolidated and significantly grew in 2020-2021. First, Valentin Picasso achieved tenure and was promoted to Associate Professor. Second, a new position of Forage systems extension was approved and will be open soon. Third, the NIFA-AFRI-SAS RESILIENCE CAP proposal was submitted (and later selected for funding) as part of a collaborative effort of the NCCC31 members and invited colleagues in areas of sociology, economics, and policy. This will expand the research, teaching, and extension on forages across the US.

2. New Facilities and Equipment

None

3. Unique Project Related Findings

Oure recent findings directly related with ecophysiology of forages include the work on Kernza intermediate wheatgrass post management practices (Pinto et al 2021), modeling of its phenological development (Duchene et al 2021), vernalization requirements (Ivancic et al 2021), and strategies to reduce plant height (Zimbric et al 2021).

4. Accomplishment Summaries

The resilience of alfalfa to variable environments grant reached its final year and we are writing the publications documenting the different resilience of alfalfa cultivars to drought and cold stress. Results from this project informed the development of the RESILIENCE CAP.

5. Impact Statements

Crop rotations with perennial forages have more stable output, and crop rotations with more diversity are more resilient to droght (Sanford et al. 2021). This is further evidence to justify the need for more forages in the landscape which is one of the goals of the new RESILIENCE CAP.

6. Published Written Works

*Refereed publications*

Pinto, P., De Haan, L., and V. Picasso. 2021. Post-Harvest Management Practices Impact on Light Penetration and Kernza Intermediate Wheatgrass Yield Components. Agronomy 2021, 11, 442. DOI:10.3390/agronomy11030442

Sanford, G.R., R. Jackson, E. Booth, J.L. Hedtcke, and V. Picasso. 2021. Perenniality and diversity drive output stability and resilience in a 26-year cropping systems experiment. Field Crops Research 263: 108071. DOI: 10.1016/j.fcr.2021.108071

Orcasberro M.S., C. Loza, J. Gere, P. Soca, V. Picasso, and L. Astigarraga. 2021. Seasonal Effect on Feed Intake and Methane Emissions of Cow–Calf Systems on Native Grassland with Variable Herbage Allowance. Animals 2021, 11, 882. DOI:10.3390/ani11030882

Duchene, O., B. Dumont, D. Cattani, L. Fagnant, B. Schlautman, L. R. DeHaan, S. Barriball, J. Jungers, V. Picasso, C. David, F. Celette. 2021. Process-based analysis of *Thinopyrum intermedium* phenological development highlights the importance of dual induction for reproductive growth and agronomic performance. Agricultural & Forest Meteorology. Vol 301–302, 108341. DOI:10.1016/j.agrformet.2021.108341

Ivancic, K., A. Locatelli, W. Tracy, and V. Picasso. 2021. Kernza Intermediate wheatgrass (*Thinopyrum intermedium*) response to a range of vernalization conditions. Canadian Journal of Plant Sciences DOI:10.1139/CJPS-2020-0251

Zimbric, J.W., D. Stoltenberg, V. Picasso. 2020. Strategies to reduce plant height in dual-use intermediate wheatgrass cropping systems. Agronomy Journal 2021;1−11. DOI:10.1002/agj2.20544

Sakiroglu, M., Dong, C., Hall, M.B., Jungers, J. and Picasso, V. 2020. How does nitrogen and forage harvest affect belowground biomass and non‐structural carbohydrates in dual use Kernza intermediate wheatgrass? Crop Science 2020; 60:2562–2573. DOI:10.1002/csc2.20239

Zimbric, J.W., D.E. Stoltenberg, V.D. Picasso. 2020. Effective weed suppression in dual-use intermediate wheatgrass systems. Agronomy Journal 112:2164-2175. DOI: 10.1002/agj2.20194

Darre, E., E. Llanos, L. Astigarraga, M. Cadenazzi, V. Picasso. 2020. Do pasture-based mixed dairy systems with higher milk production have lower environmental impacts? A Uruguayan case study. New Zealand Journal of Agricultural Research. DOI: 10.1080/00288233.2020.1750433

Siri-Prieto, G., O. Ernst, M. Bustamante, V. Picasso. 2020. Impact of nitrogen and phosphorous on biomass yield, nitrogen efficiency, and nutrient removal of perennial grasses for bioenergy. Biomass and Bioenergy 136: 105526. DOI: 10.1016/j.biombioe.2020.105526

*Book chapters*

**Cherney, J.H., R. L. Kallenbach, V. D. Picasso. 2020. Systems for temperate humid areas. Chapter 20. In: K.J. Moore, M. Collins, J. Nelson, D. Redfearn (Eds.) Forages: the science of grassland agriculture. Volume II. 7th Edition. https://doi.org/10.1002/9781119436669.ch20**

7. Scientific and Outreach Presentations

*Abstracts, symposium and conference presentations*

Picasso, V. 2020. Perenniality and diversity improve stability and climate resilience of cropping systems. ASA-CSSA-SSSA international annual meeting, on-line, USA. November 8-11, 2020.

Picasso, V. 2020. Kernza forage value, weed suppression, belowground biomass, and how to maintain grain yield over time. Fifth International Kernza Conference. On-line. June 8-12, 2020.

Picasso, V. 2020. Agroecological design of perennial polycultures for grain and forage. Polycultures and Permaculture Conference. Agriculture Sustainability Institute, University of California, Davis. February 6, 2020.

Cartoni, S. and V. Picasso. 2020. Intermediate wheatgrass (Thinopyrum intermedium) and legume dual-use polycultures in Wisconsin. ASA-CSSA annual meetings, On-line, USA.

Olugbenle, O. and V. Picasso. 2020. Optimal planting date of Kernza intermediate wheatgrass. ASA-CSSA annual meetings, On-line, USA.

Locatelli, A. and V.D. Picasso. 2020. Kernza intermediate wheatgrass variability in vernalization requirements. ASA-CSSA annual meetings, On-line, USA.

Bhatta, M., S. Bullock, L. Gutierrez, and V. Picasso. 2020. Genetics of resilience and stability to climate change in oat (Avena sativa L.). ASA-CSSA annual meetings, On-line, USA.

*Outreach publications*

**Picasso, V.** 2020. Closing the alfalfa yield gap and increasing resilience to climate change. Research update. Forage Focus. p. 8. Midwest Forage Association. August 2020.

8. Collaborative Grants

Current grants:

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)

Closing the alfalfa yield gap while improving soil health. NAFA: $ 98,002 (PI: Tautges -MFAI)

Designing an inter-row forage harvester header for use in dual- purpose grain and forage intercropping systems . USDA NIFA. $ 500,000 (PI: Schlautman – TLI)

Quantifying ecosystem services on silvopastoral systems in Peru to improve smallholder productivity. USDA FAS SCRP $ 49,970 (PI: Gomez – UNALM)

Intercropping the perennial grain Kernza with legumes for sustained economics and environmental benefits. USDA NIFA SARE$ 199,946 (PI: Jungers -UMN)

Resilience of alfalfa cultivars to variable environments USDA NIFAAFRP $299,980 (PI: Picasso – UW-Madison)

9. Graduate students and postdocs

Stefania Cartoni 6/2021 MSc Agroecology Kernza-legume intercropping

Olugakorede Olugbenle 8/2021 MSc Agroecology Kernza optimal planting date

Dante Pizarro (12/2024) PhD Dairy Science Kernza feed value & silvopasture

Soledad Orcasberro (12/2024) PhD Agronomy Alfalfa in dairy and soil health

Krishna Bhandari postdoc Alfalfa resilience to drought

Priscila Pinto postdoc K