

APPENDIX D SAES-422
Format for Multistate Research Activity
Accomplishments Report

Project/Activity Number: NCCC-31

Project/Activity Title: Ecophysiological Aspects of Forage Management

Period Covered: June 2018 to May 2019

Date of This Report: September 13, 2019

Annual Meeting Date(s): Madison, WI 17-18 July, 2019

Brief summary of minutes of annual meeting:

State	Attending members	Institution	Reported remotely
AR	Amanda Ashworth, Christine Nieman (postdoc)	ARS-USDA	
AR	Dirk Philipp	University of Arkansas	
IN	Jeff Volenec	Purdue University	
KY	Rebecca McCulley	University of Kentucky	
MA	Bill Lamp	University of Maryland	
MI	Kim Cassida	Michigan State University	Jim Kells (administrator)
ND	Marisol Berti	North Dakota State University	
OH	Marc Sulc	The Ohio State University	
OR	Guojie Wang	Oregon State University	
SD	Wu Yajun	South Dakota State University	
TN	Renata Nave	University of Tennessee	
TX	Chuck West	Texas Tech University	Vanessa Olson for Jamie Foster, Texas A&M
UT	Jennifer McAdam	Utah State University	
WI	Valentin Picasso, Ken Albrecht, John Grabber	Univ. of Wisconsin, ARS-USDA	
WY	Anowar Islam	University of Wyoming	

Not attending: Ben Tracy, Virginia Tech; Marvin Hall, Penn State (*retired*); Jeffrey Steiner, USDA (*retired*); Craig Roberts, Harley Naumman, Univ. of Missouri; John Guretzki, University of Nebraska; David Hannaway, Oregon State University.

Activities:

Wednesday July 17	
7:45 Registration and introductions	State reports (Cont.)
8:00 Administrative update	
8:10- 4:15 State reports	1:20 Texas Tech-Chuck West
8:10 Jim Kells, Michigan State University (online) presentation	1:40 Texas A&M Vanessa Olson/ for Jamie Foster online presentation
8:30 Arkansas-Dirk Philipp/Amanda Ashworth/ Christine Nieman	2:00 Utah-Jennifer MacAdam
8:50 Indiana-Jeff Volenec	2:20 Wisconsin-Valentin Picasso/ Ken Albrecht
9:10 Maryland- Bill Lamp	2:40 Wyoming- Anowar Islam
9:30 Michigan-Kim Cassida	3:00 South Dakota- Wu Yajun
	3:20 Coffee Break
9:50 Coffee Break	3:40- 5:00 Business Meeting
10:20 Tennessee- Renata Nave	- Annual report
10:40 North Dakota- Marisol Berti	- Renewal of NCCC31
11:00 Wisconsin- John Grabber	- Publishing or special issue
11:20 Ohio- Mark Sulc	5:00 Adjourn
11:40 Kentucky- Rebecca McCulley	
12:00- 1:20 Lunch	Dinner on your own

Field visit planned for July 18 was cancelled due to weather.

Business meeting minutes

- Eighteen participants (including three online participants). *Postdoc visitor*: Christine Neiman (USDA-ARS)

-Next meeting location, Laramie, WY. Host: Wyoming- Anowar Islam.

-Incoming secretary: Renata Nave

Renewal info:

-Kim Cassida is taking the lead on renewal. Important dates:

-Sept. 15, 2019 deadline to submit LOI (issues and justification statement: what are you addressing and why is it important). Project objectives need to be updated and uploaded to NIMS (Oct 15); project participants needs to be updated (Nov 1; Full proposal due). All components must be submitted online.

-Sept 30, 2020 (end of renewal period). Committee is in good standing and is perceived as a productive committee.

-Dec. 1, 2019; full proposal is due. Proposal then goes to NCAC then it gets reviewed and feedback is then provided.

-Administrative advisor Jim Kells is stepping down as chair but would like to continue as advisor to the group.

-Need to begin considerations what the new project direction will be. New innovative ideas should be included in the next 5-year plan. Should be build on from previous years. Potential sources of external funding should be leveraged.

Discussions:

-Declaration/resolution that the committee is concerned about the state of funding and forage professor position renewal in the U.S.

-*Volenc*: identify and listen to stakeholder (e.g., NAFA, NIC, Environmental Defense Fund, SHI, Farm Bureau) needs. Invite them to our meeting.

-Review article.

-Data needs. Save data. Send out NAL contact info. Long discussion of sharing raw data information. National Agriculture library as a repository for NCCC31 data.

Meeting adjourn at 11:00AM July 18

STATE REPORTS
NCC31- Ecophysiological Aspects of Forage Management, 2019 Report

Arkansas Report 2018-2019
University of Arkansas, Animal Science

1. Impact Nugget

The group from the University of Arkansas is engaged in applied research and extension activities pertaining to the use of warm season annuals and perennial, and cool season perennial forage crops. We have also extending our activities into the areas of determining N fluxes in pastures and measuring N-use efficiencies across the soil-plant-animal interface. Generated data and knowledge is published in peer-reviewed journals and summarized in extension publications such as newsletter articles and factsheets.

2. New Facilities and Equipment

Nitrogen/Carbon analyzer CosTech, CA. ~ \$40,000

3. Unique Project-Related Findings

In fall of 2018 a new NIFA-funded study was started with the aim of evaluating the effects of tannin- and polyphenols-containing forages on N-use efficiency in sheep and subsequent emissions profiles from applying collected feces and urine to plots placed in a tall fescue pasture. Diets were comprised of alfalfa silage mixed with either sericea lespedeza or lablab beans to establish tannin/phenolic levels ranging from 1.5 to 4.5 percent. Dry matter digestibility (DMD) in sheep was affected by alfalfa/lespedeza silage in such that under the high tannin treatment DMD was lower (60%) compared with the control treatment (67%). The same findings were observed for DM intake (737 g/day vs. 889 g/day, respectively). Urine and urine/feces mixes were applied based on the diet treatments onto field plots during the fall of 2018 and spring 2019 to test for emissions profiles of N₂O, ammonia, and methane. In addition, nitrates were collected from soil cores along with forage mass. Data analysis is currently underway.

Accomplishment Summaries

During 2018-2019, Arkansas (Department of Animal Science, Philipp et al.) 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. A summary of all publications from 2018-2019 is included at the end of this document.

4. Impact Statements

Issue:

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

Action:

A USDA-funded project was initiated in spring of 2018 to feed sheep with high- and low-tanning containing alfalfa/lespedeza silages as those will affect the amount of N converted in the rumen vs. bypass protein for digestion in the lower gut. Feces and urine were collected while 40 field plots were established in an existing tall fescue pasture to measure nitrous oxide, methane, carbon dioxide, and ammonia emissions and measuring nitrate leaching in soil cores of different diameters to which urine and a slurry of urine and feces was applied in fall of 2018 and spring of 2019.

Impact:

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

**Arkansas report 2018-2019
USDA-ARS, Fayetteville, AR**

1. Impact Nugget:

The USDA-ARS, Poultry Production and Product Safety Research 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:

WinRHIZO Root Scanner (Regent Instruments)
Pressure Plate Extractor (Soil Moisture)
Hydrometer for Particle Size Analysis

3. Unique Project Related Findings:

Poultry litter is a low-cost fertilizer; however, land applications can result in excessive nutrient runoff. A 14-yr study was conducted on 15 small watersheds using five management practices: continuous grazing, hayed, rotational grazing, rotational grazing with an unfertilized buffer strip, and rotational grazing with a fenced unfertilized riparian buffer. The use of unfertilized buffer strips, unfertilized fenced riparian buffer strips, or converting pastures to hayfields are effective BMPs for reducing P runoff in Southeastern U.S. pasture systems. Using metagenomic analyses, soil and water bacterial communities are being evaluated following long-term applications of combined cattle manure and poultry litter amendments and amendments solely of poultry litter. Results demonstrate that cattle manure and boiler chicken litter applications increase the prevalence of anthropogenic antibiotic resistant bacteria, however, conservation pasture management practices have the potential to disrupt resistant gene movement from soil to water systems. Overall, study results illustrate that antibiotic alternatives may result in better animal performance, increases in soil microbial diversity, while improving disease management.

Scientists from USDA/ARS and University of Arkansas research partners developed a decision support tool that promotes the adoption 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%. Researchers determined that auto-guided tractors reduce on-farm inputs by as much as 20% and 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. The team of federal and university researchers developed Tractor Guidance Analysis software for providing tailored estimates of the economic and environmental benefits of adopting automated tractor guidance technology. The software incorporates parameters tailored to reflect the size of different farming operations and generates estimates for: 1) actual reductions in seed, organic and inorganic fertilizer, and chemical inputs given differing terrain attributes; 2) efficiency gains and feasibility of technology adoption by determining break-even prices based on farming operation type, farm size, and capital investment requirements; and 3) subsequent soil health and water quality impacts from reducing agricultural inputs based on in-field data. This tool was released in 2018, and scientists have provided hands-on training to producers and scientists via field days and stakeholder meetings. To date, the Tractor Guidance Analysis software has been especially effective in advancing the use of auto-guided tractors and self-propelled machinery on pastures, operations that traditionally have not adopted precision agriculture technologies.

4. Accomplishment Summaries:

During 2018-2019, 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 2018-2019 is included at the end of this document. Selected project summaries are listed below in detail.

5. Impact Statements

A long-term (14 year) study was conducted utilizing 15 small watersheds to determine the impacts of pasture management strategies (over grazing, rotational grazing, buffer strips, riparian buffer strips and haying) on pasture hydrology, erosion and nutrient, and pathogen runoff. Phosphorus runoff was reduced by 36% with unfertilized buffer strips, 60% with fenced, unfertilized riparian buffers and 49% by converting pastures to hayfields. These results show the use of buffer strips and converted pastures to hayfields can be very effective best management practices (BMPs) for reducing phosphorus runoff in Southeastern U.S. pastures. Researchers developed a decision support tool that promotes the adoption 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%. Researchers determined that precision agriculture platforms can improve gains in equipment efficiency and enhance yields in forage systems. Further, by providing producers an estimate of both economic and environmental repercussions of tractor guidance, adoption of this technology is expected to increase.

5. Published Written Works

Refereed Journal Articles

Martin, J.W., P.A. Moore, Jr., H. Li, A.J. Ashworth, and D.M. Miles. 2018. Effects of land-applied

- ammonia scrubber solutions on yield, nitrogen uptake, phosphorus runoff, and soil test phosphorus. *J. Environ. Quality* 47: 263-269.
- Burner, D.M., A.J. Ashworth, K.F. Laughlin, and M.E. Boyer. 2018. Using Google SketchUp to simulate tree row azimuth effects on alley shading. *Agron. J.* 110: 1-6.
- Lindsay, K., M. Popp, C. West, A.J. Ashworth, A. Rocateli, R. Farris, G. Kakani, F. Fritschi, S. Green, M.W. Alison, and M. Maw. 2018. Predicted harvest time effects on switchgrass moisture content, nutrient concentration, yield, and profitability. *Biomass & Bioenergy* 108: 74-89.
- Ashworth, A.J., F.L. Allen, J. DeBruyn, P.R. Owens, and C. Sams. 2018. Crop rotations and poultry litter impact dynamic soil chemical properties and soil biota long-term. *J. Environmental Quality. Special Section: Soil Chemistry and the One Health Initiative.* 47:1327-1338. doi:10.2134/jeq2017.12.0465
- Adhikari, K., P.R. Owens, A.J. Ashworth, T.J. Sauer, Z. Libohova, and D.M. Miller. 2018. Topographic controls on soil nutrient variations in a silvopasture system. *Agrosystems, Geosciences & Environment* 1:180008. doi:10.2134/age2018.04.0008
- Ashworth, A.J., H.D. Toler, R.M. Augé, and F.L. Allen. 2018. Global meta-analysis reveals agro-grassland productivity varies based on species diversity over time. *PLOS ONE.* 13(7): e0200274 <https://doi.org/10.1371/journal.pone.0200274>
- Pilon, C., P.A. Moore, Jr., D.H. Pote, J.W. Martin, P.R. Owens, A.J. Ashworth, D.M. Miller, and P.B. DeLaune. 2018. Grazing management and buffer strip impact on nitrogen runoff from pastures fertilized with poultry litter. *J. Environ. Quality. Special Section: Riparian Buffer Management.* 48:297-304. doi:10.2134/jeq2018.04.0159
- Popp, M., A.J. Ashworth, P.A. Moore, Jr., P.R. Owens, J.L. Douglas, D.H. Pote, A.A. Jacobs, K.R. Lindsay, and B. Dixon. 2018. Fertilizer recommendations for switchgrass: quantifying economic effects on quality and yield. *Agronomy Journal* 110: 1854-1861. doi:10.2134/agronj2018.04.0273
- Ashworth, A.J., Lindsay, K., M. Popp, and P.R. Owens. 2018. Economic and environmental impact assessment of tractor guidance technology. *Agricultural & Environmental Letters* 3:1-5. doi:10.2134/ael2018.07.0038
- Lindsay, K., M. Popp, A.J. Ashworth, P.R. Owens, and J. Burek. 2018. A decision support system for analyzing tractor guidance technology. *Computers and Electronics in Agriculture* 153: 115-125. doi.org/10.1016/j.compag.2018.08.014
- Acharya, M., D. Burner, A.J. Ashworth, F. Fritschi, T.C. Adams. 2018. Growth rate of Giant Miscanthus (*Miscanthus x giganteus*) and Giant Reed (*Arundo donax*) in a low-input system in Arkansas, USA. *Am. J. Plant Sciences* 9: 2371-2384. DOI: 10.4236/ajps.2018.912172
- Braden, I.S., A.J. Ashworth, and C.P. West. 2019. Spatial soil nutrient-plant-herbivore linkages: A case study from two poultry litter-amended pastures in Northwest Arkansas. *Agrosystems, Geosciences & Environment* 2:180036. doi:10.2134/age2018.09.0039
- Jiang, Y., Z. Sun, P.R. Owens, K. Adhikari, Q. Wang, M.J. Dorantes, J.J. Read, A.J. Ashworth, and Z. Libohova. 2019. Spatial distribution of soil phosphorus, calcium, and pH after long-term broiler litter application. *J. Environ. Qual.* 48:594-602. doi:10.2134/jeq2018.11.0406
- Burgess-Conforti, J.R., P.A. Moore, Jr. P.R. Owens, D.M. Miller, A.J. Ashworth, P.D. Hays, M.A. Evans-White, and K.R. Anderson. 2019. Are soils beneath coniferous tree stands more acidic than soils beneath deciduous tree stands? *Environmental Science and Pollution Research.* 26:14930–14931. doi: 10.1007/s11356-019-04883-y
- Dold, C. T. Sauer, A. Thomas, A.J. Ashworth, D. Brauer, and D. Phillipp. Carbon sequestration

- and nitrogen uptake in a temperate silvopasture system. 2019. *Nutrient Cycling in Agroecosystems* 114: 85–98. doi: 10.1007/s10705-019-09987-y
- Adams, T., D. Philipp, D.M. Burner, J. Jennings, B. McPeake, A.J. Ashworth, D.H. Pote, J.M. Burke, and R. Rhein. White (*Trifolium repens* L.) and arrowleaf (*Trifolium vesiculosum* Savi) clover emergence in varying loblolly pine (*Pinus taeda* L.) tree alley spacings. 2019. *American Journal of Plant Sciences*.10: 659-669. DOI: 10.4236/ajps.2019.104048
- Lepore, A.W., A.J. Ashworth, P. Kim, N. Labbé, R.M. Connaster, and F.L. Allen. 2019. Feasibility and concurrent remediation of red mud as an in situ pyrolysis catalyst. *Bioresources*. 12: 4696-4707.
- Ashworth, A.J., P.A. Moore, Jr., R. King, J.L. Douglas, D.H. Pote, E. Pratt, and A.A. Jacobs. Switchgrass forage yield and compositional response to phosphorus and potassium. 2019. *Agrosystems, Geosciences & Environment*. 2:190010. doi:10.2134/age2019.02.0010
- Yang, Y., K.M. Feye, Z. Shi, H.O. Pavlidis, M. Kogut, A.J. Ashworth, S. C. Ricke. *Accepted*. A historical review on antibiotic resistance of foodborne campylobacter. *Frontiers in Microbiology*.

Book Chapters

- Sauer, T.J., C. Dold, A.J. Ashworth, A. Thomas, Y.G. Chendev, D. Philipp, A Gennadiev, and G.H. Ramirez. *In press*. Agroforestry Practices for Soil Conservation and Resilient Agriculture. *In* R. Udawatta and S. Jose (Eds.) *Ecosystems Services of Agroforestry*.
- Ashworth, A.J., J.P. Chastain, and P.A. Moore, Jr. *In press*. Characteristics of poultry manure and litter. *In* H. Waldrip, P.H. Pagliari, and Z. He (Eds.) *Animal Manure: Production, Characteristics, Environmental Concerns and Management*. Soil Science Society of America Monograph. Madison, WI.

6. Scientific and Outreach Presentations

- Ashworth, A.J., P.A. Moore, Jr., D.H. Pote, P.R. Owens, J.W. Martin, and K.R. Anderson. 2019. Developing best management strategies for reducing soluble phosphorus losses from poultry litter in grazing systems. International Interdisciplinary Conference on Land Use and Water Quality, Agriculture and the Environment. Aarhus, Denmark.
- Moore, P.A. Jr., K. Anderson, C. Pilon, J. Martin, D.H. Pote, P.R. Owens, A.J. Ashworth, D. Miller and P. DeLaune. 2019. Long-term study on the effects of buffer strips and grazing management on phosphorus runoff from pastures. American Society of Agronomy, Southern Branch Meeting. Birmingham, Alabama.
- Ashworth, A.J., P.R. Owens, K. Adhikari, T. Adams, T.J. Sauer, D. Philipp, and A. Thomas. 2019. Spatially variable landscape attributes drive soil nutrients, soil moisture, forage growth, and preferential grazing in silvopastoral systems. [CD-ROM]. American Society of Agronomy, Crop Science Society of America (ASA and CSSA), International Meetings, Madison, WI.
- Ashworth, A.J., P.R. Owens, K. Adhikari, T. Adams, T.J. Sauer, D. Philipp, and A. Thomas. 2019. Spatially variable landscape attributes drive soil nutrients, soil moisture, forage growth, and preferential grazing in silvopastoral systems. [CD-ROM]. American Society of Agronomy, Crop Science Society of America (ASA and CSSA), International Meetings, Madison, WI.
- Ashworth, A.J., J. DeBruyn, F.L. Allen, P.R. Owens, and C. Sams. 2018. The One Health approach to poultry litter and cover crop management in cropping systems after 12 years of management. [CD-ROM]. ASA and CSSA, International Meetings, Madison, WI.

- Yang, Y., A. Ashworth, L. Durso, K. Cook, C. Willett, J. DeBruyn, P. Owens, P. Moore, and M. Savin. 2018. Identification of soil microbiota and antibiotic resistance genes in soils receiving long-term poultry litter. [CD-ROM]. ASA and CSSA, International Meetings, Madison, WI.
- Ashworth, A.J., F.L. Allen, J. DeBruyn, P.R. Owens, and C. Sams. 2018. Long-term cropping system rotation and poultry litter impact soil physiochemical properties. 21st World Congress of Soil Science, Rio de Janeiro, Brazil.
- Adams, T., A.J. Ashworth, P.R. Owens, K. Adhikari, T.J. Sauer, D. Philipp, and A. Thomas. 2018. Preferential grazing based on soil characteristics in a silvopasture system. 9th Annual UMCA Agroforestry Symposium, Columbia, MO.
- Yang, Y., A.J. Ashworth, A. Upadhyay, A.M. Donoghue, B. Khatri, J.D. Latorre, G. Tellez-Isaias, B.M. Hargis, B.W. Kong, and Y.M. Kwon. 2018. The isolation and identification of probiotics as an antibiotic alternative in poultry industry. ARS-FSIS Food Safety Meeting, Shepherdstown, WV.
- Acharya, M. A.J. Ashworth, D.M. Burner, D. Pote, J., Burke, and J.P. Muir. 2018. Evaluation of yield and nutritive value of three browse species for feeding small ruminants during summer. Southern Pasture & Forage Crop Improvement Conference. Fayetteville, AR.
- Lindsay, K., M. Popp, P.R. Owens, and A.J. Ashworth. 2018. Decision support for economic and environmental impact of tractor guidance on small crop and livestock farms. Southern Agricultural Economics Association. Jacksonville, FL.
- Ashworth, A.J., P.R. Owens, M. Popp, and K.R. Lindsay. 2018. Economic and environmental assessment of tractor guidance technologies. International Commission of Agricultural and Biosystems. Antalya, Turkey.
- Owens, P.R., A.J. Ashworth, and Z. Libohova. 2018. A pattern recognition approach combined with Fuzzy Logic for predicting soil properties and function. International Commission of Agricultural and Biosystems. Antalya, Turkey.
- Ashworth, A.J., A.W. Lepore, F.L. Allen, R.M. Connaster, P. Kim, and N. Labbé. 2018. Use of red mud as a pyrolysis catalyst and a carbonated soil amendment. Food and Agriculture Organization of the United Nations. Global Symposium on Soil Pollution. Rome, Italy.
- Adhikari, K., P.R. Owens, L. West, A.J. Ashworth, M.A. Wilson, D.M. Miller. 2018. Geostatistical mapping of metal elements distribution across conterminous USA. Food and Agriculture Organization of the United Nations. Global Symposium on Soil Pollution. Rome, Italy.
- Zechiel, K., J. Rhinehart, G. Bates, A.J. Ashworth, and C. Boyer. 2018. Evaluation of five warm-season forages for beef cattle production. American Forage and Grassland Council. Annual Conference, Louisville, KY.

7. Collaborative Grants

2019 USDA-Agricultural Research Service funding Opportunity in Antimicrobial Resistance, “Identifying Best Management Practices for Disrupting AMR Gene Transmission to the Environment” \$71,405 for 2019-2022 with Amanda Ashworth, Cammy Willett, Lisa Durso, Phillip Owens, Philip Moore, and Jennifer DeBruyn.

2019 Southern Sustainable Agriculture Research and Education, Research and Education, “Innovative nutrient management options for sustainable pasture land intensification” \$296,498 for 2019-2022 with Mike Popp Dr. Phillip Owens, Ken Coffey, Amanda Ashworth, Christine Nieman, Johnny Gunsaulis, and Grant West.

2018 Foundation for Food and Agriculture, New Innovator, “Plant-Soil-Water Nexus: Critical Agricultural Systems Research on Tribal Lands” \$599,214 for 2018-2020 for 2018-2020 with Amanda Ashworth, Janie Hipp, Phillip Owens, and Dave Miller.

2018 USDA-Office of Technology Transfer, Innovation Fund, “Quantifying Air and Water Quality Benefits of Improved Poultry Manure Management Practices” \$25,000 for 2018-2019 with Amanda Ashworth, Phillip Owens, and Michael Popp.

2018 USDA-Agricultural Research Service funding Opportunity in Antimicrobial Resistance, “Evaluating Mitigation Strategies for the Reduction of Antimicrobial Resistance Gene Transfer from Animal Hosts to the Environment” \$79,000 for 2019-2022 with Amanda Ashworth, Annie Donoghue, Yichao Yang, Yong Wang, Cammy Willett, Abhi Upadhyay, Michael Rothrock, and Kim Cook.

8. Graduate students

Jason Burgess-Conforti, PhD, The Potential Acidification of the Mulberry River, Arkansas, 2019.

Indiana Report 2018-109
Purdue University

1. Impact Nugget:

Very high biomass yields were produced with *Miscanthus*.

The agronomic and environmental performance of biomass and maize production systems can be accurately modeled in APSIM and SWAT.

Proper P and K fertility is critical to yield and persistence of alfalfa. High yield is associated with larger, not more shoots. Mass/shoot might serve as a target for alfalfa improvement programs.

2. New Facilities and Equipment:

No new facilities or equipment to report.

3. Unique Project Related Findings:

In a long-term alfalfa P and K fertility study plant death was exacerbated (over unfertilized controls) when P was applied without to plants growing in low K soils.

Alfalfa plant death occurred during “summer” (May to Dec.) and was not associated with winterkill (death between Dec. to May).

Taproot N reserves (amino-N, protein), and not C reserves (starch, sugars) are associated with fertility-enhanced differences in alfalfa performance.

4. Accomplishment Summaries:

Modeling

Feng et al. (2018) evaluated potential production of switchgrass (*Panicum virgatum*) and *Miscanthus* (*Miscanthus* × *giganteus*) on marginal lands in the Upper Mississippi River Basin (UMRB). A SWAT model with detailed representation of marginal lands and their suitability for growth of the two grasses was setup. Marginal land was defined as cropland and grassland with land capability class 3 to 8. All marginal lands were included as new land covers in the land use map and were preserved when HRUs were defined. The SWAT model was calibrated for flow at 13 sites within the UMRB region at monthly scale. The predicted biomass by growing switchgrass and *Miscanthus* on marginal lands in the study area can produce up to 37% of the 132 billion liter biofuel goal set by the 2010 Energy Independence and Security Act in the US. The simulated flow was lower when marginal lands were converted to grow perennial bioenergy crops. The results from this study improved our understanding on growth of perennial crops on marginal land and their contributions to biofuel development.

Nutrient Management

Berg et al. (2018) used cluster analysis to determine how alfalfa plant persistence is altered by P and K fertilization, and determine if changes in specific taproot C and/or N reserves were associated with alfalfa plant death. Taproots were dug and plants counted in May and December of each year and taproots analyzed for P, K, starch, sugar, amino-N, and soluble protein. K-means clustering was used to create six clusters that were subsequently compared using two-sample t-tests. Low K in herbage and taproots was associated with low yield and poor persistence of the Low and Very Low clusters and taproots of these plants generally had low starch, protein, and

amino-N concentrations. Plants died primarily between May and December. Plant persistence of the low yielding, P-deficient Medium cluster was high and associated with high starch concentrations. Low amino-N concentrations in taproots may provide an early indication of potential plant death because these were evident in poor-persisting Low and Very Low clusters early in the study.

In a follow-up study (Berg et al., submitted) these authors examines how these nutrients alter taproot physiology during fall acclimation and subsequent growth in spring in poorly understood. Our objectives were to: 1) determine seasonal patterns for taproot P and K concentrations during fall acclimation, winter, and during initial shoot growth in spring; 2) determine how P and K nutrition impacts accumulation of taproot C and N reserves during fall and their subsequent use when shoot growth resumes in spring; and 3) assess how P and K fertility-driven differences in accumulation and use of C and N reserves impacts survival and shoot growth in spring. A factorial arrangement of two P (0 and 75 kg ha⁻¹) and two K (0 and 400 kg ha⁻¹) treatments were replicated in the field four times. Fertilizer treatments were applied following the May and September harvests with half the specified fertilizer amounts in each application. Roots were sampled over two winters, initially following defoliation in mid Sep, and 7, 14, 21, 28, 42, 56, 70, and 84 days after shoot removal until winter dormancy in early Dec, and weekly in the spring following the end of winter dormancy (approximately March 25) until the first forage harvest in May. Concentrations of taproot sugar, starch, buffer-soluble protein, and amino-N pools were determined. Forage yield in May was highest for the 400K-75P treatment, and least for the 0K-0P treatment; differences that were associated with variation in mass/shoot. High yield of the 400K-75P plants in May was consistently associated with greater concentrations of amino-N and soluble protein in taproots, and not with starch and sugar concentrations. Understanding factors leading to the accumulation of taproot N reserves during fall acclimation and their use during the initial growth in spring should enhance efforts to improve alfalfa yield and stress tolerance.

Crop Management

Zumpf et al. (2019) evaluated warm-season grasses for biomass production potential under different harvest timings (summer [H1], after killing frost [H2], or alternating between two [H3]) and nitrogen (N) fertilizer rates (0, 56, and 112 kg N/ha) on a wet marginal land across multiple production years. Six feedstocks were evaluated including *Miscanthus x giganteus*, two switchgrass cultivars (*Panicum virgatum* L.), prairie cordgrass (*Spartina pectinata* Link), and two polycultures including a mixture of big bluestem (*Andropogon gerardii* Vitman), indiagrass (*Sorghastrum nutans*), and sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), and a mixture of big bluestem and prairie cordgrass. Across four production years, harvest timing and feedstock type played an important role in biomass production. *Miscanthus x giganteus* produced the greatest biomass (18.7 Mg/ha), followed by the switchgrass cultivar “Liberty” (14.7 Mg/ha). Harvest in H1 tended to increase yield irrespective of feedstock; the exception being *M. x giganteus* that had significantly lower biomass when harvested in H1 when compared to H2 and H3. The advantage H1 harvest had over H2 for all feedstocks declined over time, suggesting H2 or H3 would provide greater and more sustainable biomass production for the observed feedstocks. The N application rate played an important role mainly for *M. x giganteus* where 112 kg N/ha yielded more biomass than no N. Other feedstocks occasionally showed a slight, but statistically insignificant increase in biomass yield with increasing N rate. This study showed the potential of producing feedstocks for bioenergy on wet marginal land; however, more research on tissue

and soil nutrient dynamics under different N rates and harvest regimes will be important in understanding stand longevity for feedstocks grown under these conditions.

Mitchell et al. (2018) determined the impact of biochar on growth and root development of crabgrass. They grew plants in rhizoboxes filled with a sandy loam field soil +/- biochar (2% wt wt⁻¹). Two types of biochar produced by slow pyrolysis at 450 °C were used: a low-nutrient biochar produced from a mixture of softwoods and a high-nutrient biochar produced from loblolly pine and switchgrass. Two soil patterns were used: solid (rhizobox filled uniformly with field soil +/- biochar) and split (unamended and amended field soil, each occupying half of the rhizobox vertically). Plants were completely randomized in two growth chambers and grown for 38 days after transplanting. Root systems were scanned with a flatbed PC scanner and images were analyzed using ImageJ with SmartRoot. Plant biomass was dried and weighed. Root growth of large crabgrass varied with the type of biochar used; however, biochar did not affect total plant dry weight. High-nutrient biochar increased aboveground dry weight and low-nutrient biochar increased belowground dry weight when compared to plants grown in the unamended soil. Large crabgrass roots grew preferentially in the half of the rhizobox amended with biochar regardless of type. Root biomass was 74 and 79% greater in soil with low-nutrient and high-nutrient biochar respectively than in the unamended soil. This study suggests that the addition of biochar to soils, regardless of feedstock or nutrient content, will likely increase the ability of large crabgrass to spread above-ground or below-ground by increased root growth. Large crabgrass roots preferentially seek out proliferate in biochar-enriched soils.

Crop Improvement

Rivera-Burgos et al. (2019) assessed yield and quality of lignocellulosic biomass enhancement for ethanol production potential in a population of sorghum derived from two cultivars with contrasting biomass yield and compositional traits. We tested 236 recombinant inbred lines (RILs) of sorghum in a randomized complete block design (RCBD) with two replications for lignocellulosic biomass performance and determined hemicellulose, cellulose and lignin concentrations through detergent fiber analysis (DFA). The DFA results were used to estimate theoretical ethanol yield and production. Results showed that RILs carrying the brown midrib mutation had significantly high theoretical glucose recovery (>200 g kg⁻¹). Those carrying both mutations, had high theoretical ethanol yield (>400 L ton⁻¹) and high theoretical ethanol production (>14,500 L ha⁻¹). Lignin concentration was determined as most reliable predictor (R²= 0.67) for glucose recovery. Lignin and stem sugar concentrations (R²= 0.46 and 0.35, respectively) were good predictors for ethanol yield. Stover yield traits (R²= 0.89) were most important determinants for ethanol production. Our findings suggest that careful breeding of sorghum for genetic enhancement of biomass quantity and quality could double lignocellulosic ethanol yields.

Taylor et al. (2018) identified genetic variations and candidate genes for controlling heading and anthesis in segregating switchgrass populations. Four pseudo-F2 populations (two reciprocal crosses) were developed from lowland (late flowering) and upland (early flowering) ecotypes, and heading and anthesis dates of these populations were collected in Lafayette, IN and DeKalb, IL in 2015 and 2016. Across two years, there was a 34 and 73 day difference in heading and a 52 and 75 day difference in anthesis at the Lafayette and DeKalb locations, respectively. A total of 37,901 single nucleotide polymorphisms were obtained from 588 genotypes from the populations by exome capture sequencing. A genome wide association study identified five significant signals at multiple loci including three for heading and two for anthesis. Among them, a homolog of FLOWERING LOCUS T on chromosome 5b associated with heading date was identified at the

Lafayette location across two years. A homolog of ARABIDOPSIS PSEUDO RESPONSE REGULATOR 5, a light modulator in the circadian clock associated with heading date was detected on chromosome 8a across locations and years. These results demonstrate that identified genetic variants related to floral development could lend themselves to a long-term goal of developing late flowering varieties of switchgrass with high biomass yield.

5. Published Written Works

Refereed Publications

- Ojeda, J.J., J.J. Volenec, S.M. Brouder, O.P. Caviglia, M.G. Agnusdei. 2018. Modelling stover and grain yields, and subsurface artificial drainage from long-term corn rotations using APSIM. *Agric. Water Manage.* 195:154–171.
- Berg, W.K., S. Lissbrant, S.M. Cunningham, S.M. Brouder, and J.J. Volenec. 2018. Phosphorus and potassium effects on taproot C and N reserve pools and long-term persistence of alfalfa (*Medicago sativa* L.). *Plant Sci.* <https://doi.org/10.1016/j.plantsci.2018.02.026>.
- Taylor, M.S., C.-E. Tornqvist, X. Zhao, P. Grabowski, R. Doerge, J. Ma, J.J. Volenec, J. Evans, G. P. Ramstein, M. D. Sanciangco, C. R. Buell, M.D. Casler., and Y. Jiang. 2018. Genome-wide association study in pseudo-F2 populations of switchgrass identifies genetic loci affecting heading and anthesis dates. *Front. Plant Sci.* 9:1250 <https://doi.org/10.3389/fpls.2018.01250>
- Feng, Q., I Chaubey, R. Cibin, B. Engel, K.P. Sudheer, J.J. Volenec, and N. Omani. 2018. Perennial biomass production from marginal land in the Upper Mississippi River Basin. *Land Degrad. Develop.* <https://doi.org/10.1002/ldr.2971>.
- Mitchell, K., E. French, J. Beckerman, A. Iyer-Pascuzzi, J.J. Volenec, and K. Gibson. 2018. Biochar alters the root systems of large crabgrass. *Hortsci.* 53:354–359. <https://doi.org/10.21273/HORTSCI12690-17>.
- Zumpf, C., M.-S. Lee, S. Thapa, J. Guo, R. Mitchell, J.J. Volenec, and D.K. Lee. 2019. Impact of warm-season grass management on feedstock production on marginal farmland in Central Illinois. *GCB Bioenergy* DOI: 10.1111/gcbb.12627. p. 1-13.
- Rivera-Burgos, L.A., J. J. Volenec, and G. Ejeta. 2019. Biomass and bioenergy potential of brown midrib sweet sorghum germplasm. *Front. Plant Sci.* (in press).

Book Chapters

- Volenec, J.J. and C.J. Nelson. 2018. Environmental aspects of forage management. Chapter 5. pp. 71-86. In: M. Collins, C.J. Nelson. K.J. Moore and D.D. Redfearn (eds.) *Forages-An Introduction to Grassland Agriculture. Volume I. 7th Edition.* John Wiley & Sons, Inc., New York, NY.
- Volenec, J.J. and C.J. Nelson. 20xx. Carbon metabolism in forage plants. Chapter 4. In: M. Collins, C.J. Nelson. K.J. Moore and D.D. Redfearn (eds.) *Forages-The Science of Grassland Agriculture. Volume II. 7th Edition.* John Wiley & Sons, Inc., New York, NY. (in press).
- Brouder, S.M. and J.J. Volenec. 20xx. Mineral nutrient acquisition and metabolism. Chapter 5. In: M. Collins, C.J. Nelson. K.J. Moore and D.D. Redfearn (eds.) *Forages-The Science of Grassland Agriculture. Volume II. 7th Edition.* John Wiley & Sons, Inc., New York, NY. (in press).

Other Publications

- Cherney, J.H., K.A. Albrecht, M.T. Berti, M. Bohle, S.C. Bosworth, K.A. Cassida, W.J. Cox, E. Creech, S.C. Fransen, M.H. Hall, D.B. Hannaway, M.A. Islam, K.D. Johnson, J.W. MacAdam, E.C. Meccage, D.H. Putnam, E.B. Rayburn, C.C. Sheaffer, G. Shewmaker, J. Solomon, R.M. Sulc and J.J. Volenec. 2018. Forage in crisis: Forage crops don't get no respect. *Progressive Forage* 8:14-16.
- Bowling, L., M. Widhalm, K. Cherkauer, J. Beckerman, S.M. Brouder, J. Buzan, O. Doering, J.S. Dukes, P. Ebner, J. Frankenberger, B. Gramig, E. Kladivko, C. Lee., J.J. Volenec, and C. Weil. 2018. Indiana's Agriculture in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment. Purdue Climate Change Research Center, Purdue University. West Lafayette, Indiana. <https://ag.purdue.edu/indianaclimate/agriculture-report/>

Abstracts

- Ghazanfarpour, N., S.M. Brouder, and J.J. Volenec. 2018. Prediction of tile drainage and crop yield from long-term corn rotations using the DSSAT model in the Midwestern United States. <https://scisoc.confex.com/scisoc/2018am/meetingapp.cgi/Paper/112825>
- Volenec, J.J., S.M. Brouder, and T.S. Murrell. 2019. Broadening the objectives of future potassium fertilizer recommendations. *Soil Sci. Soc. Amer. Meeting*, Jan. 6-9, 2019. San Diego CA. <https://scisoc.confex.com/scisoc/2019sssa/meetingapp.cgi/Paper/116297>

6. Scientific and Outreach Presentations

- Volenec, J.J. 2018. Climate change impacts on crop and livestock systems. African Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation Conference, August 20-24, Haramaya University, Ethiopia.
- Volenec, J.J., S.M. Brouder, and T.S. Murrell. 2019. Broadening the Objectives of Future Potassium Fertilizer Recommendations. *Soil Sci. Soc. Amer. Meeting*, Jan. 6-9, 2019. San Diego CA.

7. Collaborative Grants

- USDA-NIFA-AFRI. Cover cropping for Sustainable Co-Production of Bioenergy, Food, Feed (BFF) and Enhancement of Ecosystem Services (ES). S.M. Brouder, R.F. Turco, J.J. Volenec, I. Chaubey. Apr. 1, 2017 to Mar. 31, 2021. \$500,000.
- Foundation for Food and Agricultural Research (FFAR) and the 4R Research Fund. Coordinated Site Network for Studying the Impacts of 4R Nutrient Management on Crop Production and Nutrient Loss. M. Helmers (PD), S.M. Brouder, L. Christianson, K. Nelson, D. Jaynes, L. Gentry, C. Drury, F. Fernandez, A. Eagle, J.J. Volenec. Oct. 1, 2017 to Sept. 30, 2020. Total: \$2,000,000; Purdue Share: \$324,365.
- Dow-DuPont. Agronomic and environmental performance of nitrification inhibitors. S.M. Brouder, R.F. Turco, and J.J. Volenec. Oct. 1, 2017 to Sept. 30 2019. \$100,000
- USDA-NIFA-AFRI. The NutriNet Knowledgebase for Synthesis of North American Tile Drainage Research. S.M. Brouder (PD), J.J. Volenec, M. Helmers, L. Christianson, L. Abendroth. May 1, 2019 to April 30, 2024. \$500,000.
- USDA-NIFA-AFRI. FACT: An Innovative Cyber-Framework Integrating Public/Private Data for Evidence-Based Recommendations. S.M. Brouder (PD), J.J. Volenec, C. Barford, W.K. Berg,

G. Bossaer, S. Brandt, C. Cai, B. Craig, N. DeLay, B. Erickson, M. Ruark, T.S. Murrell, J. Scott, N. Thompson, D. Walker, J. Zhu. Aug. 1, 2019 to July 31, 2024. \$1,000,000

8. Graduate students

Brody Deno, MS, 5/2020, “Impact of cover cropping and mulch cropping on yield and environmental performance of maize and soybean”

Kentucky report 2018-2019

University of Kentucky

1. Impact Nugget

The forage group at the University of Kentucky 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.

2. New Facilities and Equipment

The University of Kentucky is transforming 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 will be called the Grain & Forage Center of Excellence, is located in Princeton, KY, and houses one UK Forage Extension Specialist – Dr. Chris Teutsch. A ribbon cutting ceremony for the new building is slated for Sept. 19, 2019.

3. Unique Project-Related Findings

Grasslands in North America are increasingly threatened by land conversion and ecological degradation, prompting restoration efforts to increase native plant species diversity and improve wildlife habitat. A major challenge is the removal and management of non-native invasive species such as tall fescue (*Schedonorus arundinaceus*), which has a symbiotic association with a fungal endophyte (*Epichloë coenophiala*) that modifies its ecological interactions. Using transplanted clumps of the cultivar Kentucky-31, we tested the effects of endophyte infection on tall fescue's survival and performance (tiller production, flowering, and basal area) for five years in a central Kentucky reconstructed prairie. We predicted that endophyte infected (E+) clumps would have increased performance compared to endophyte-free (E-) clumps. Overall, E+ clumps had greater survival, tiller production, flowering tiller production, and basal area, but not reproductive effort (proportion of tillers flowering) as compared to E- clumps. However, survival and trends in tiller number and basal area over the five year period suggested experimental tall fescue populations were in decline in the reconstructed prairie, although the E- population declined more rapidly. Our study provides evidence that endophyte infection improved tall fescue's growth and survival in a post-reconstruction plant community, at least in the early years following reconstruction, and may increase the invasive potential of this non-native species in prairie restorations.

4. Accomplishment Summaries

During 2018-2019, 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 included the delivery of our findings through various in-service training sessions, field days, schools, farm visits, interaction with producer and commodity groups, and via numerous extension outlets. We completed the second version of our climate change study (detailed below) and we continued the field and lab work associated with the symbiotic diversity project.

5. Impact Statements

“Utilizing grass-endophyte technology to improve pasture soil health and resilience to climate change stressors”

Issue: Agronomists and the grass seed industry have long recognized the value in manipulating plant-endophyte symbioses to improve pasture sustainability. Significant resources have been devoted to the ongoing discovery and deployment of novel endophyte technology, where the production of 'good' alkaloids is maintained but the 'bad' ergots are not. However, to date, the development of these 'symbiotically modified organisms' has focused primarily on maintaining fescue stand persistence and insect resistance, while improving animal performance, under current climatic conditions. The primary tenet of this project is that manipulation of these plant-microbe associations can also improve forage production resilience and forage quality under future warmer and potentially drier conditions. Furthermore, adoption of new grass-endophyte technology may have repercussions for a variety of soil health parameters, which may also affect pasture resilience and feedbacks to climate change.

Action: We completed the third growing season of our manipulative warming and altered precipitation regime field project, where we are evaluating a suite of grass-endophyte combinations for their ability to tolerate these stressful conditions. We have collected two full years of soil-to-atmosphere trace gas fluxes, which we are in the process of analyzing. We have also evaluated rates of endophyte seed transmission to see if the climate treatments produce a disconnect between the grass host and fungus. We are also analyzing plant production and alkaloid data, and have sampled some of the material for a full leaf and root microbiome analysis.

Impact: Overall, we observe that some grass-endophyte combinations are considerably better able to withstand the environmental stress produced by the climate treatments than others - illustrating the need to evaluate stress responses for novel combinations entering the market. It is important to thoroughly evaluate the resilience of new agricultural plant material to stressors such as climate change.

“Biodiversity effects on grassland response to nutrients and herbivory”

Issue: Human land use is driving biodiversity loss world-wide, including increasingly homogenizing plant communities. As species and their interactions are important in determining the function of ecosystem, e.g. nutrient retention or resilience to climate variability, loss of biodiversity may have major effects on the provisioning of ecosystem services.

Action: Research conducted at the University of Kentucky and a global network of grassland sites (NutNet) assessed the relationship between plant diversity and ecosystem multifunctionality at local and landscape scales. We measured plant diversity and ecosystem functions, including aboveground live biomass, resource capture aboveground (light interception), resource pools belowground (% total soil nitrogen and extractable soil phosphorus and potassium), soil carbon storage, litter decomposition, and invasion resistance, at 65 grassland sites located on five continents.

Impact: Our results provide robust evidence that plant diversity at the local and landscape scale is associated with more reliable functioning of grassland ecosystems. Human activities that simplify ecosystems through the loss of plant diversity are likely to diminish the capacity of systems to

supply essential ecosystem functions. The maintenance and restoration of plant diversity at local and landscape scales should help ensure the reliable provision of ecosystem services.

6. Published Written Works

Refereed Journal Articles

- Rounsaville, T.J., R.L. McCulley, and M.A. Arthur. 2019. Allee effects and soil nutrient changes mediated by experimental plantings of a nonindigenous, temperate liana. *Plant Ecol.* 220(9):861-872.
- Seabloom, E.W., B. Condon, L. Kinkel, K.J. Komatsu, C.Y. Lumibao, G. May, R.L. McCulley, and E.T. Borer. 2019. Effects of nutrient supply, herbivory, and host community on fungal endophyte diversity. *Ecology* e02758.
- Yang, Z., S. Chen, X. Liu, D. Xiong, C. Xu, M.A. Arthur, R.L. McCulley, S. Shi, and Y. Yang. 2019. Loss of soil organic carbon following natural forest conversion to Chinese fir plantation. *Forest Ecol. Manag.* 449: 117476. doi: 10.1016/j.foreco.2019.117476
- Moore, J.D., A.E. Carlisle, J.A. Nelson, and R.L. McCulley. 2019. Fungal endophyte infection increases tall fescue's survival, growth, and flowering in a reconstructed prairie. *Restoration Ecology*. doi: 10.1111/rec.12960
- Crowther, T.W., C. Riggs, E.M. Lind, E.T. Borer, E.W. Seabloom, S.E. Hobbie, J. Wubs, P.B. Adler, J. Firn, L. Gherardi, N. Hagenah, K.S. Hofmockel, J.M.H. Knops, R.L. McCulley, A. MacDougall, P.L. Peri, S.M. Prober, C.J. Stevens, and D. Routh. 2019. Sensitivity of global soil carbon stocks to combined nutrient enrichment. *Ecology Letters* 22(6):936-945. doi: 10.1111/ele.13258
- Cleland, E.E., E.M. Lind, N.M. DeCrappeo, E. DeLorenze, R.A. Wilkins, P.B. Adler, J.D. Bakker, C.S. Brown, K.F. Davies, E. Esch, J. Firn, S. Gressard, D.S. Gruner, N. Hagenah, W.S. Harpole, Y. Hautier, S.E. Hobbie, K.S. Hofmockel, K. Kirkman, J. Knops, C.W. Kopp, K.J. La Pierre, A. MacDougall, R.L. McCulley, B.A. Melbourne, J.L. Moore, S.M. Prober, C. Riggs, A.C. Risch, M. Schuetz, C. Stevens, P.D. Wragg, J. Wright, E.T. Borer, and E.W. Seabloom. 2019. Belowground biomass response to nutrient enrichment depends on light limitation across globally distributed grasslands. *Ecosystems*. doi: 10.1007/s10021-019-00350-4
- Bradford, M.A., R.L. McCulley, T.W. Crowther, E.E. Oldfield, S.A. Wood, and N. Fierer. 2019. Cross-biome patterns in soil microbial respiration predictable from evolutionary theory on thermal adaptation. *Nature Ecol. Evol.* 3(2):223-231. doi: 10.1038/s41559-018-0771-4
- Nogueira, C., A. Nunes, M.N. Bugalho, C. Branquinho, R.L. McCulley, and M.C. Caldeira. 2018. Nutrient addition and drought interact to change the structure and decrease the functional diversity of a Mediterranean grassland. *Frontiers in Ecology and Evolution* 6: article 155. doi: 10.3389/fevo.2018.00155

Other Peer Reviewed Publications

- Odom, L., K. Mazcko, J. Derner, C. Dell, R. McCulley, C. Carey, J. Kucera, A. Franzluebbers, D. Knaebel, and D. Manter. 2018. Assessing and managing for soil health on rangelands and pasture lands. *Foundations in Food and Agriculture Research* white paper. <https://foundationfar.org/wp-content/uploads/2018/06/Rangeland-Soil-Health-White-Paper-6.6.18.pdf>

Extension Publications

- Henning, J., G. Olson, and R. Smith. 2018. Long-term summary of Kentucky forage variety trials. PR-754.
- Bruening, B. and J. Henning. 2018. Annual grass report: Warm season and cool season (cereals). PR-753.
- Henning, J., R. Smith, and C. Teutsch. 2018. Cool-season grass horse grazing tolerance report. PR-752.
- Henning, J. and G. Olson. 2018. Cool-season grass grazing tolerance report. PR-751.
- Henning, J. and G. Olson. 2018. Red and white clover grazing tolerance report. PR-750.
- Henning, J. and G. Olson. 2018. Alfalfa grazing tolerance report. PR-749.
- Henning, J. and G. Olson. 2018. Annual and perennial ryegrass and festulolium report. PR-748.
- Henning, J. and G. Olson. 2018. Timothy and Kentucky bluegrass report. PR-747.
- Henning, J. and G. Olson. 2018. Tall fescue and brome grass report. PR-746.
- Henning, J. and G. Olson. 2018. Orchardgrass report. PR-745.
- Henning, J., G. Olson, and R. Smith. 2018. Red and white clover report. PR-744.
- Henning, J., G. Olson, and R. Smith. 2018. Alfalfa report. PR-743.

7. Scientific and Outreach Oral Presentations

- McCulley, R.L. 2019. Evaluating Grazingland Soil Health – Identifying Challenges and Opportunities. SSSA Annual Meeting, San Diego, CA.
- McCulley, R.L., K. Saikkonen, M. Helander, I. Zabalgogezcoa, and B.R. Vazquez de Aldana. 2018. Effects of *Epichloë* endophytes on grassland greenhouse gas fluxes and soil carbon: results from a Trans-Atlantic study. International Fungal Endophyte of Grasses Symposium, Salamanca, Spain.

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*. 2017-2021. \$500,000
- McCulley, R.L. (PI), J. White, and C.A. Young (Co-PIs). “Can manipulation of fungal endophyte diversity positively influence tall fescue pasture sustainability and ecosystem functioning?” *NIFA-AFRI-Foundational – Agroecosystem Biodiversity*. 2016 – 2018. \$150,000
- R.L. McCulley (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

9. Graduate Students

- Mahtaab Bagherzadeh**, MS in Integrated Plant & Soil Sciences, **2018**, “Can increasing grass-fungal endophyte symbiotic diversity enhance grassland ecosystem functioning?”
- Alayna Jacobs**, PhD in Integrated Plant & Soil Sciences, expected graduation **2022**, title – TBD.
- Katie Payne**, PhD in Integrated Plant & Soil Sciences, **2019**, “Enhanced efficiency nitrogen formulation effect on grass-legume pasture productivity.”

Maryland report 2018-2019
University of Maryland

1. Impact Nugget:

Understanding the complex interactions between insect pest populations, injury, and forage crop physiology can aid producers to optimize yield, quality, and stand persistence. For example, potato leafhopper, *Empoasca fabae*, causes short-term disruption of gas exchange and translocation in alfalfa physiology, yet the interaction between the pest and crop can be managed by the producer. By integrating management practices, producers can reduce leafhopper injury and maintain forage crop production in a profitable and environmentally-safe manner.

2. New Facilities and Equipment:

No new facilities or equipment to report.

3. Unique Project Related Findings:

Our findings suggest that potato leafhopper reduces nitrogen uptake from soil as well as nitrogen fixation, however the ratio of the source varies with soil nutrient conditions and leafhopper injury. Understanding the complex physiological interactions between leafhopper injury on gas exchange and translocation on one hand, and nutrient uptake by passive (soil-derived N) and active (atmosphere-derived N) mechanisms will require additional research.

In addition, we found that potato leafhopper injury significantly reduces stomatal conductance in the field, resulting in a higher canopy temperature. The effect of potato leafhopper on canopy temperature is variable, and is made more difficult to measure when the canopy is not yet filled. This is an issue because leafhopper management generally requires a decision early in the growth cycle, before the ground is coverage by foliar tissue.

4. Accomplishment Summaries:

Nitrogen allocation altered by leafhopper injury across cultivars and cropping systems. M. Thompson and W. Lamp.

Nitrogen acquisition and allocation limits the success of perennial crops over multiple growing seasons. Severe pest pressure can reduce the nutritional content of crops, resulting in losses for growers. Potato leafhopper (PLH; *Empoasca fabae*, Hemiptera: Cicadellidae) remains one of the most significant pests of *Medicago sativa*, reducing growth and forage quality through feeding damage. Management strategies, such as planting resistant cultivars and intercropping with grasses, offer ways to control PLH pressure. Whether PLH feeding alters nitrogen acquisition and allocation, however, remains unclear. To test this, our objectives were to quantify the effect of PLH injury on nitrogen biomass and allocation across resistant and susceptible cultivars and understand the effect of intercropping on PLH injury across cultivars. We implemented a field experiment, establishing a randomized complete block split-plot design at the Western Maryland Research and Education Center in Keedysville, Maryland. Main plots included: 1) Susceptible Monoculture, 2) Susceptible-Fescue Intercropped, 3) Resistant Monoculture, and 4) Resistant-Fescue Intercropped. We established subplots using a pyrethroid insecticide (Warrior II) to vary PLH pressure. We collected whole-plant samples in June 2018 and separated shoots, crowns, and roots. Under PLH pressure, resistant cultivars accumulated higher aboveground nitrogen biomass but intercropping with fescue did not affect accumulation. Our results advance sustainable management strategies for forage growers by comparing the effectiveness of two PLH management strategies.

Nutrients modify nitrogen fixation and whole-plant response to herbivory. M. Thompson and W. Lamp.

Beneficial soil microbes engage in mutualisms with plant roots, aiding plants in nutrient acquisition. In return, plants donate photosynthate as an energy source for microbes. Nitrogen-fixing plants, for instance, live symbiotically with mutualistic microbes, such as *Rhizobium* and *Frankia*, which extract inert nitrogen gas from the atmosphere in exchange for carbon. Disrupted basal translocation of fixed carbon from leaves to roots, however, could negatively impact plant-rhizobia interactions. Aboveground insect herbivory can reduce photosynthate production, which may cascade to alter belowground interactions. Whether aboveground herbivory indirectly alters belowground nitrogen fixation, however, remains unclear. To test this, my objectives were to determine differences in fixed nitrogen allocation across whole plants in response to herbivory and identify if plants can recover from herbivore-induced losses to nitrogen fixation with additional soil nitrogen. We tested these objectives in a greenhouse setting using three nitrogen fertilization levels (none, low, high) and varied herbivory (with PLH, without PLH). To calculate nitrogen fixation, we used fixing and non-fixing varieties of alfalfa. We collected whole plant samples and separated plants into shoots, crowns, and roots. We found that plants differentially allocated fixed nitrogen in response to herbivory depending on soil nitrogen conditions. Herbivory induced greater aboveground allocation of fixed nitrogen in plants grown with no additional nitrogen whereas high levels of soil nitrogen induced the opposite response. Low soil nitrogen levels resulted in no nitrogen fixation and, therefore, no differences in whole-plant allocation. Overall, our work advances our understanding on the context dependency of how herbivory can indirectly influence interactions of plants with beneficial organisms.

4. Impact Statements

Leafhopper injury can be a significant loss to alfalfa production. By providing management options to producers, we hope to reduce their losses by enabling them to optimize their strategy for alfalfa pest management. Resistant varieties, in particular, may be a valuable tool now, while in the past variety selection did not reflect increased profit margins. The use of alternative methods to assess insect injury, such as through radiation sensing, may provide an easier and quicker means to develop a response to insect pests. By investigating the complex insect-plant interactions that lead to leafhopper injury, and incorporating that understanding with the management tools available to producers, ecophysiological research can aid to make forage production more sustainable in light of variable pest populations in the future.

5. Published Written Works

Refereed publications

Avanesyan, A., K. Snook, P. Follett, and W. Lamp. 2019. Short-term physiological response of a native Hawaiian plant, *Hibiscus arnottianus*, to injury by the exotic leafhopper, *Sophonia orientalis* (Hemiptera: Cicadellidae). *Environmental Entomology* 48: 363-369.

Grant, J., and W.O. Lamp. 2018. Degree day requirements for kudzu bug (Hemiptera: Plataspidae), a pest of soybeans. *Journal of Economic Entomology* 111: 700-706.

Leslie, A., and W. Lamp. 2019. Burrowing macroinvertebrates alter phosphorus dynamics in drainage ditch sediments. *Aquatic Sciences* 81:23 (online).

6. Scientific and Outreach Presentations

3/19, invited speaker, “Beneficial Biodiversity Associated with Agricultural Drainage Ditches on the Delmarva Peninsula”, DELMARVA Cooperative Seed Grant Program Summit, Newark, DE.

7. Collaborative Grants

2017-20, USDA-Alfalfa and Forage Research Program, lead PD with Mark Sulc and James Jasinski (Ohio State University) and Yong-Lak Park and Tom Griggs (West Virginia University) as co-PDs, “Proximal and remote sensing of alfalfa canopies for early detection of insect stress and rapid integrated pest management decision-making”, \$289,993. The purpose of this grant is to develop proximal (handheld) and remote (UAVs) sensors of alfalfa canopies for rapid decision-making concerning leafhopper injury.

2015-2019, USDA-Alfalfa and Forage Research Program, lead PD with Mark Sulc (Ohio State Univ.) and Kenneth Albrecht (Univ. of Wisconsin) as co-PDs, “Potato Leafhopper Threshold Revised for Alfalfa Host Resistance and Alfalfa-Grass Mixtures”, \$215,000. The purpose of this grant is to determine economic loss relationships for potato leafhopper in alfalfa cropping systems, to examine the effect of the leafhopper on nitrogen fixation, and to extend new information on economic thresholds.

8. Graduate students

Morgan Thompson, MS, 5/2019, “Evaluating the effect of potato leafhopper (*Empoasca fabae*) feeding on biological nitrogen fixation in alfalfa (*Medicago sativa*).

Rebecca Wilson, PhD, 12/2018, “Spatial distribution, habitat preference, and societal impact of the nuisance black fly, *Simulium jenningsi*”.

Michigan 2018-2019 report Michigan State University

1. Impact Nugget

None.

2. New Facilities and Equipment

FOSS DS2500 NIR Spectrophotometer

3. Unique Project-Related Findings

- Genetically modified reduced lignin alfalfa varieties have improved forage quality with similar yield to high quality standard varieties.
- Preliminary results indicate it is feasible to develop a soil bioassay for alfalfa autotoxicity.

4. Accomplishment Summaries

Multi-site Performance of Reduced Lignin Alfalfa. Plots were established in 2014 as part of a six-state (MI, WI, KS, OH, CA, PA) industry- funded trial to evaluate the relationship of harvest maturity to forage quality in new reduced-lignin alfalfa (RLA) varieties. Yield and forage quality data were collected in all states from 2015-16 and in Michigan only from 2017-18. Final stand density was determined in Michigan by destructive sampling in spring 2019. In 2017, a new 4-year trial was established in six states (MI, WI, KS, OH, CA, UT) to examine the impact of the next generation of reduced lignin genetics, harvest schedule, and fungicide treatment on alfalfa yield, quality, and persistence. *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.

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 GREEN 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:* Preliminary results from the four-state trial indicate that success of the system is highly dependent on site characteristics and weather. In Michigan in 2018, one site out of four was a complete failure for alfalfa stand. Conditions that favor corn tend to disadvantage alfalfa.

Developing a Soil Bioassay for Alfalfa Autotoxicity. Funding was obtained in 2018 from the US Alfalfa checkoff and in 2019 from Project GREEN to explore feasibility of a bioassay to evaluate autotoxicity potential in field soils. The objective is to develop a rapid-turnover test for plant diagnostic laboratories that can be used to predict success of re-establishing alfalfa in potentially autotoxic soils. *Key Outcomes and other accomplishments realized:* Preliminary results suggest a soil-on-agar assay can successfully identify reductions in seedling root growth after four days of growth. The next step is validation of these results in the greenhouse and field.

Precision Agriculture Tools for Optimizing Alfalfa Production and Marketing. Funding was received in 2018 from NIFA-AFRP with three objectives: 1. Identify spectral signatures for pre-harvest alfalfa and its primary companion grasses; 2. Use spectral unmixing algorithms to determine pre-harvest yield, nutritive composition, and abundance of alfalfa and grass in a mixture; and 3. Develop extension materials to assist in adoption of precision technologies in alfalfa production. Collaborators are MSU and the University of Wisconsin at River Falls. *Key Outcomes and other accomplishments realized:* In 2019, spectral signatures were collected under Objective 1, mixtures were planted use in 2020 for objective 2, and a field day was held in East Lansing under Objective 3.

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 in 2017-2018. *Key Outcomes and other accomplishments realized:* These data were distributed to farmers, industry and made available to other researchers for “big data” analysis.

5. Impact Statements

- Genetically modified reduced lignin alfalfa varieties have improved forage quality and similar yield to standard varieties.

6. Published Written Works

Refereed Journal Articles:

- Arnold, A.M., K.A. Cassida, K.A. Albrecht, M.H. Hall, D.H. Min, X. Xu, S. Orloff, D.J. Undersander, E. van Santen, and R.M. Sulc. Multi-state evaluation of reduced lignin alfalfa harvested at different intervals. *Crop Sci.* 59:1799-1807. doi:10.2135/cropsci2019.01.0023

Bulletins and Factsheets:

- Cassida, K., and J. Lindquist. 2018. *Frost-Seeding – an Effective Forage Establishment Practice for Michigan.* MSUE #E2125, 8 pp. <https://forage.msu.edu/wp-content/uploads/2018/08/E2185-FrostSeedingAnEffectiveForageEstablishmentPracticeForMichigan-2018.pdf> (Bulletin, reviewed)
- Cassida, K., J. Paling, and C. Kapp. 2019. *2018 Michigan Forage Variety Test Report.* MSU Forage Factsheet 19-01, 37 pages. Published Feb. 1, 2019. Online. <https://forage.msu.edu/wp-content/uploads/2019/02/2018-MichiganStateUniversityVarietyTrialReport-WebVersion.pdf> (Accessed 3/21/19). (Factsheet)
- Cassida, K., J. Lindquist, and R. Ehrhardt. 2019. *Low-Cost Renovation Practices for Perennial Pastures and Hayland in Michigan.* MSUE Bulletin #E3310, 8 pp. <https://forage.msu.edu/wp-content/uploads/2019/02/E3310-LowCostRenovationPracticesForPerennialPasturesHaylandInMichigan-FINAL.pdf> (Bulletin, reviewed)
- Cassida, K. M. Jean, and P. Kaatz. 2019. *Emergency Hay and Silage Forage Crops.* Forage Factsheet #19-03. Published online 7/12/19 <https://www.canr.msu.edu/resources/emergency-hay-and-silage-forage-crops> . (Factsheet)

Farm Press Articles:

- Cassida, K. 2019. Forage research field day a success. *Michigan Hay & Grazer* 14:1-2. Michigan Forage Council, East Lansing, MI.

Web Articles:

- Cassida, K.A. 2019. March is Frost-Seeding Month in Michigan. Published Mar. 21, 2019. *MSUE Ag News*, https://www.canr.msu.edu/news/march_is_frost_seeding_month_in_michigan. Featured in *Morning Ag Clips*, 3/22/19. (Web Article)
- Cassida. 2019. When Alfalfa Winter Kills, What Can You Do? *MSUE Ag News*, Online 5/17/19, https://www.canr.msu.edu/news/managing_stand_losses_in_alfalfa_fields. Featured in *Morning Ag Clips*, 5/21/19, <https://www.morningagclips.com/when-alfalfa-winterkills-what-can-you-do/> (Web article)
- Singh, M. and K. Cassida, 2019. Agronomic Guidelines for Late-Planted Corn Silage. *MSUE Ag News*, published online 6/28/19. <https://www.canr.msu.edu/news/agronomic-guidelines-for-late-planted-silage-corn>. Lead article *Morning Ag Clips*, 7/1/19, <https://www.morningagclips.com/agronomic-guidelines-for-late-planted-silage-corn/>. (Web article)
- Cassida, K. and M. Jean. Emergency Hay and Silage Forage Crops. *MSUE Ag News*, Published online 7/1/19. <https://www.canr.msu.edu/news/emergency-hay-and-silage-forage-crops> (Web article)
- Cassida, K. 2019. Forage research field day scheduled for July 31. *MSUE Ag News*, Published online 7/12/19, <https://www.canr.msu.edu/news/forage-research-field-day-scheduled-for-july-31>
- Lead article *Morning Ag Clips* July 16, 2019. <https://www.morningagclips.com/forage-research-field-day-scheduled-for-july-31/> (web article)
- Cassida, K. 2019. Last minute emergency forage planting options. *MSUE Ag News*, Published online Aug. 6, 2019. <https://www.canr.msu.edu/news/last-minute-emergency-forage-planting-options> (web article)
- Cassida, K. 2019. Forage Research Field Day A Success. *Michigan Hay & Grazer* 14:1-2. Michigan Forage Council, East Lansing, MI. (Newsletter article)

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)

7. Scientific Outreach and Oral Presentations

Abstracts and Posters:

- Thompson, L.R., I.C.F. Maciel, K.A. Cassida and J.E. Rowntree. 2019. Comparison of grazing systems with differing forage diversity. *J. Anim. Sci* (in press). Annual Meeting, July 8-11, 2019, Austin, TX. (abstract)

Reports:

- Cassida, K.A. 2018. NCCC-31 Annual Report. Madison, WI. June 17-18, 2019.
- Cassida, K.A. Midwest Cover Crops Council Annual Report-Michigan. Springfield, IL. March 20, 2019.

Extension presentations:

- July 31, 2019. Forage Field Day. East Lansing, Michigan. (35 participants)
- June 27, 2019. Value of Cover Crops. General Mills grower meeting, Shepherd, MI. (Invited, 17 participants)
- May 16, 2019. Assessing Alfalfa Stands for Winter Damage. MSUE Field Crops Virtual Breakfast Meeting.
- March 7, 2019. Forage and Pasture Resources for the Michigan Horse Industry. Michigan Horse Council Priorities Meeting. East Lansing, MI. (25 participants)
- March 5, 2019. MSU Forage Research Update. Great Lakes Forage & Grazing Conference, St. Johns, MI. (100 participants)
- Feb. 8, 2019. The Value of Cover Crops. Crop Update, Shepherd, MI (35 participants)
- Feb. 7, 2019. The Value of Cover Crops. Crop Update, Richland, MI (25 participants)
- Jan. 24, 2019. Silvopasture Train The Trainer Meeting, Tustin, MI. (via Zoom)
- Jan. 23, 2019. Silvopasture Train The Trainer Meeting. Chatham, MI (via Zoom)
- January 16, 2019. Interseeding Alfalfa into Corn. MABA Annual Conference, Lansing, MI. (invited, 50 participants)
<https://www.youtube.com/watch?v=Yc4rl3VJoww&feature=youtu.be>
- January 16, 2019. MSU Cover Crop Variety Trials. MABA Annual Conference, Lansing, MI. (invited, 50 participants) <https://www.youtube.com/watch?v=y6-M3r25sUU&feature=youtu.be>
- Dec. 20, 2018. “Forage/Cover Crop Update. Field Crops Agronomy Update. East Lansing MI. (Audience: 25)
- Dec. 18, 2018. Forage Research Update. 2018 Integrated Crop and Pest Management Update. MSUE, East Lansing MI (Audience 200)
- Nov. 29, 2018. Reduced lignin trait in alfalfa: results from multi-state trials. California Alfalfa & Forage Symposium, Nov. 27-29, 2018, Reno NV. Audience: 125. (Invited)
- Nov. 14, 2018. “Soils, alfalfa fertility, and manure management,” Alfalfa establishment,” Harvest management,” “Grazing alfalfa,” and “Value of alfalfa in rotations.” Alfalfa Intensive Training Seminar, National Alfalfa and Forage Assoc., Nov. 13-14, 2018, Minneapolis, MN. 40 participants. (invited)

8. Collaborative Grants (NCCC31 members bolded)

- **Cassida, K., D. Undersander, K. Albrecht, V. Picasso, D.H. Min, M. Sulc, D. Putnam,** and E. Creech. 2018-2019. Low lignin alfalfa trials. Forage Genetics International. \$20,000.

9. Graduate Students

None

North Dakota Report 2018-2019
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

3. Unique Project Related Findings:

Accomplishments summaries:

My main research accomplishments are indicated below:

Obj. 1. Forage crops

In 2018, activities included testing alfalfa varieties and other forages. Results are published in the forages website (<http://www.ag.ndsu.edu/plantsci/forage/index.html>).

In 2018, the forages experiments included:

a) *Silage corn-alfalfa intercropping:* The objective of this research was to evaluate the productivity and profitability of corn-alfalfa intercropping system. Corn grain yield decreases in about 30 bu/acre, but alfalfa forage yield in the next year increases in 2.5 ton/acre skipping the seeding year and benefiting of a full season of growth. This system can provide a head start for alfalfa skipping the typical low productivity of the seeding year. Also an on-farm replicated strip-trial version of this experiment was conducted in Valley City, ND, with promising results. This project was completed in 2018.

b) *Mixtures for forage grazing:* A new study was conducted this year to test five forage mixtures and compared them with two forage sorghum-millet blends. In summary, annual ryegrass, chicory, and plantain mixtures were the lowest yielding mixtures as well as turnip-hybrid brassica mixtures. Sorghum mixtures which were in a 2-cut system worked better than full-season 1-cut system sorghum mixes. Sorghum seeding rate must be reduced to only 1 lb/acre to allow other species in the mix to thrive.

c) *Winter rye forage and silage variety trials.* Seven silage hybrids and grain check varieties were tested. The spring was very dry so in general both biomass and grain yield were low.

d) *Forage sorghum variety trial.* As reported before forage sorghum is the highest biomass yielding crop for forage in North Dakota. In a two cut systems, forage sorghum had both high forage yield and quality.

Obj. 2. Bioenergy crops

a) *Forage sorghum chilling-tolerance.* Forage sorghum's limitation as energy crop is its low chilling tolerance which doesn't allow for an earlier seeding date in ND. The experiment started in 2017 and in 2018 the experiment was replicated at two additional locations. Cultivar by date was significant for biomass yield indicating some of the identified cultivars had greater yield when planted early in May. Results were published in the Proceedings of the European Biomass Conference in Copenhagen, Denmark.

b) *Life cycle assessment of forage sorghum-corn intercropping for biogas:* Corn silage used for biogas production in Europe has a negative impact in the environment, by growing sorghum and corn together, silage yield and quality does not decrease and the environmental impact is minimized. The results of this LCA were published in the Journal of Cleaner Production and presented at two international conferences in 2018.

c) *Perennial forage grasses*: Twelve different species of perennial grasses, eight cool-season and four warm-season grasses under rain-fed conditions have been evaluated annually since 2014 both for forage and potential as bioenergy crop.

Obj. 3. Cover crops for forages

a) *Cover crops variety and seeding date trial*: The experiment was established in 2018 in Fargo on two seeding dates, July 30 and August 10. All results of biomass yield, and N accumulation of cover crops are available in the forages web page.

b) *Interseeding of legumes into standing corn*

The experiment was planted at Hickson and Prosper, ND in 2018. Five different cover crops were interseeded in two corn at two growth stages V8 and R4. Only faba bean and rye established well and reduced the available soil nitrate in the inter row of corn protecting it from potential leaching and runoff.

c) *Development of NIR calibrations for cool- and warm-season cover crops biomass*. Calibrations for NIR forage quality and seed quality analysis were developed. We are able to analyze for protein, N, ash, and P content, warm- and cool-season cover crops biomass, forage sorghum and corn biomass at different developmental stages, forage brassicas and camelina seed oil, protein, and fatty acid composition. Additionally, we have full forage quality and seed quality calibrations for alfalfa and grass, wheat, soybean, and corn seed.

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 3,098,298 acres in 2018. **Forages are the fourth most important crop in acreage in ND** after wheat, soybean and corn. Alfalfa alone (without including mixtures) had more acres planted than each one of the following crops: sunflower, oat, pea, lentil, flax, sugarbeet, and potato. The optimization of alfalfa management greatly impacts forage productivity. Diverse studies in alfalfa harvest management and fertility conducted by this project have demonstrated forage yield can be easily increased on average at least by 0.3 ton/acre/yr. Pure alfalfa acreage in ND in 2017 was 449,046 acres and alfalfa-grass mixtures 962,015 acres. An increase in forage yield of 0.3 tons/acre/year x 1,411,062 acres (alfalfa & alfalfa-grass mixtures) @ \$100/ton of hay equals an economic impact of **\$42,331,852/yr**. Alfalfa-corn intercropping allows alfalfa to get established in the corn year. This system increases alfalfa yield in Year 2 in 2.5 tons/acre compared with a spring-seeded alfalfa. Corn yield decreases in 30 bu/acre due to competition with alfalfa. But in two years the gain of the system is about \$160/acre (2.5 tons/acre x \$100/ton – 30 bu/acre x \$3/bu corn) or \$80/acre/yr. The acres of corn silage-alfalfa rotation in ND are about 150,000 acres x \$80= **\$1,200,000** in monetary impact.

The impact of bioenergy crops research it is hard to value monetarily, since there is not commercial production of energy crops in North Dakota yet. But forage sorghum can yield up to 10 tons of dry matter/acre at \$30-50/ton for biomass feedstock gross income will be \$300-500/acre. In 2017, forage sorghum acreage was 35,843 acres at \$30/ton value by 5 tons/acre as feed the economic impact equals **\$5,376,450/yr**.

Legume cover crops planted after wheat in one of our studies reduced the need of fertilizing in corn by 80 lbs N/acre, but this is not likely to occur every year and in every field. Additionally, the research of interseeding cover crops into standing corn and soybean 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 20 lbs/acre, the economic

value of reducing the fertilization in corn in 3,316,142 acres x 20 lbs N/acre saving x \$0.3 lb N, is **\$19,896,858/yr**. Cover crops forage value can add \$30-\$50/acre revenue by grazing. If only 10% of the wheat acreage (6,539,986 acres) was planted to cover crops for grazing after harvest, the economic impact would be **\$19,619,958/yr**.

All indicators in surveys to farmers, indicate a strong increase in adoption of cover crop interseeding into corn and soybean and use of cover crops after wheat for grazing (number of acres interseeded or grazed are not available, but we estimate they are surpassing 300,000 acres in ND). The adoption on interseeding and broadcasting cover crops into standing corn and soybean are a direct impact of this research project with funding coming from the USDA-NIFA CAP grant.

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 fertilizer rates in corn, 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 to the state= \$88,425,118 annually.

5. Published written work

Peer-reviewed publications

Aponte, A. D. Samarappuli, and M.T. Berti. 2019. Alfalfa grass-mixtures in comparison to grass and alfalfa monocultures. *Agron. J.* 111:1-11. doi: 10.2134/agronj2017.12.0753

Berti, M.T. and D. Samarappuli, 2018. How does sowing rate affect plant and stem density, forage yield, and nutritive value in glyphosate-tolerant alfalfa? *Agronomy* 8: 169 doi:10.3390/agronomy8090169

Samarappuli, D. and M.T. Berti. 2018. Intercropping forage sorghum with maize is a promising alternative to maize silage for biogas production. *J. Cleaner Prod.* 194:515-524

Proceedings and Abstracts

Berti, M.T., S. Podder, S. Cabello, B. Andersen, D. Samarappuli, A. Peterson, J.V. Anderson. 2018. Chilling-tolerant forage sorghum as a potential bioenergy feedstock in North Central USA. In 26th European Biomass Conference and Exhibition. 14-17 May 2018, Copenhagen, Denmark. Available at <http://www.etaflorence.it/proceedings/index.asp> (verified 10 May 2018).

6. Scientific and Outreach Presentations

Berti, M.T. 2019. Interseeding, nutrient cycling, alfalfa-corn intercropping, and winter camelina studies. Annual Coordinated Agricultural Program (CAP) project. Fargo, ND, 26-27 March, 2019.

Berti, M.T. 2018. Where to start with cover crops. 14th Annual Conservation Tillage Conference, Fargo, ND, 18-19 December 2018. Invited speaker.

Berti, M.T. 2019. Alfalfa management and production. Grazing Cover Crops Workshop, Dickinson, ND, 4 March 2019.

Berti, M.T. 2019. Cover crops North Dakota report. Midwest Cover Crops Annual Conference. Springfield, IL. 20-21 February 2019.

Berti, M.T., S. Podder, D. Samarappuli, A. Peterson, and W. Zegada-Lizarazu. 2018. Forage sorghum: a good crop for forage and fuel production in the northern Great Plains in the USA. 2nd European Sorghum Congress Milan, Italy, 7-8 November 2018.

- Podder, S., M.T. Berti, S. Cabello-Leiva, B. Andersen, D. Samarappuli, A. Peterson, J.V. Anderson, and A. Wittenberg. 2018. Chilling-tolerant forage sorghum as a potential bioenergy feedstock in North Central US. ASA-CSSA International Annual Meetings, Baltimore, MD, 4-7 November 2018.
- Andersen, B. and M.T. Berti. 2018. Faba bean (*Vicia faba* L.) as a cover crop, intercrop and late-season forage in the Midwest. ASA-CSSA International Annual Meetings, Baltimore, MD, 4-7 November 2018.
- Berti, M.T., B.L. Johnson, H. Kandel, J. Ransom, A. Wick, D. Franzen, D. Ripplinger, J. Nowatzki, A. Peterson, M.S. Wells, A. Lenssen, S. Patel, R.W. Gesch, F. Forcella, and H. Matthees. 2018. CROPSYS-CAP- A novel management approach to increase productivity, resilience, and long term sustainability of cropping systems in the northern Great Plains- Research Update. 30th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Pathway to commercialization of Industrial Crops. London, Ontario, Canada 23-26 September 2018. Keynote speaker (General crops division)
- Berti, M.T., S. Podder, D. Samarappuli, and A. Peterson. 2018. Forage sorghum: a good crop for forage and fuel production in the northern Great Plains in the USA. In: Sorghum in the 21st century. Cape Town, South Africa, 9-13 April 2018.
- Berti, M.T. 2018. Alfalfa-corn intercropping. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
- Andersen, B., M.T. Berti, D. Samarappuli, A. Peterson, S. Cabello, and S. Podder 2018. Faba bean (*Vicia faba* Roth.) as cover crop, intercrop, and late-season forage. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
- Podder, S., M.T. Berti, A. Peterson, S. Cabello, B. Andersen, and D. Samarappuli. 2018. Screening forage sorghum [*Sorghum bicolor* (L.) Moench] genotypes for chilling-tolerance. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
- Andersen, B., M.T. Berti, D. Samarappuli, A. Peterson, S. Cabello, and S. Podder 2018 Integrating faba bean (*Vicia faba* Roth.) as cover crop, intercrop, and late-season forage .Production Agriculture Symposium Univ. of Minnesota. Minneapolis, MN, 15 February 2018.
- Podder, S., M.T. Berti, A. Peterson, S. Cabello, B. Andersen, and D. Samarappuli. 2018. Screening forage sorghum [*Sorghum bicolor* (L.) Moench] genotypes for chilling-tolerance Production Agriculture Symposium Univ. of Minnesota. Minneapolis, MN, 15 February 2018.
- Berti, M.T. 2018. Is forage sorghum a good alternative crop for forage and biofuel in the northern Plains? Center for Sorghum Improvement Seminar. Kansas State University, Manhattan, KS, 8 January, 2018. Invited speaker

Other publications (magazines, extension/online/bulletins)

- Berti, M.T. 2019. Manage for winterkill. Forage Focus, August 2019. p.3.
- Berti, M.T. 2019 Hybrid rye variety trial. Forage Focus, August 2019. p.9
- Berti, M.T. Full-season cover crops mixtures for grazing. Forage Focus, March 2019. p. 6
- Wick, A., M.T. Berti, and L. Briese. Starting with cover crops in North Dakota. Midwest Cover Crops Council cover crop recipe. Bull MCCC-102. Available at mccc.msu.edu.statesprovince/north-dakota/
- Berti, M.T., 2018. Alfalfa-corn intercropping may increase forage and improve soil health. North Dakota Research Report. Forage Focus, December 2018, p. 17.

- Berti, M.T., 2018. Cutting management strategies of first-cut alfalfa. 2018. Forage Focus, May 2018, p. 10.
- Kandel, H., A. Wick and M. Berti. 2018. NDSU Extension Sets Cover Crop Field Day (Rutland)
- Berti, M.T. and H. Kandel. 2018. Extension cover crop field day August 28. Morning AgClips Farming News, Harvested Daily. August 20, 2018.
- Berti, M.T. and M.S. Wells. Research update field day. Morning AgClips Farming News, Harvested Daily. September 10, 2018 at <https://www.morningagclips.com/ndsu-extension-cover-crop-field-day-sept-18/>
- Berti M.T., and A.W. Wick. 2018. Avoiding another year of ‘snirt’. Country Guide. October 31, 2018.
- Berti M.T. 2018. Seven soil health takeaways. Dakota Farmer. October 23, 2018

7. Collaborative grants

- 2019-2021 USDA-NIFA- ASAFS Alfalfa management practices and their effect on arbuscular mycorrhizal fungi (AMF) populations- towards improving health, productivity, and sustainability of alfalfa production” \$429,011. In collaboration with Heike Bucking and Sara Bauder South Dakota State University
- 2019-2020 NAFA. Alfalfa-checkoff. Potassium fertilization and its impact on yield, quality, and winter hardiness of alfalfa. \$37,270.
- 2018-2020 NC-SARE. PDP. Cover crops and forage grazing training program in North Dakota. \$74,555. In collaboration with Kevin Sedivec and Abbey Wick, NDSU.
- 2016-2020 AFRI-NIFA CAP –Agricultural Production Systems. CropSys-CAP- A novel management approach to increase productivity, resilience, and long-term sustainability of cropping systems in the northern Great Plains. \$3,739,199 12 researchers included. ND, MN, and IA

8. Graduate students

- Kenneth Mozea, MS:** Full-season cover crops grazing mixtures. Expected graduate 2021
- Amy Greenberg, MS:** Potassium fertilization in alfalfa. Expected Graduation 2021.
- Swarup Podder, MS:** Cold tolerance in forage sorghum. Graduated May 2019

Oregon report 2018-2019
Oregon State University

1. Impact Nugget
2. New facilities and Equipment
3. Accomplishments

Oregon State University Extension and Research faculty have initiated a “Forage and Livestock Systems” working group. The mission of this working group is to increase collaboration on planning and executing high priority projects. One collaborative project, led by David Hannaway, is developing an “Oregon Forages” website (<https://forages.oregonstate.edu/oregon>). This website, primarily focused on Oregon, will include 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 developing sustainable agricultural systems. This site will simplify the search for information by county agents and specialists, farmers and ranchers, and agricultural agency personnel and build stronger linkages among research, outreach, and classroom and eCampus teaching efforts.

Research Project Descriptions

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

Evaluation of adding Se to fertilizers to increase forage Se concentration and reduce livestock Se deficiency. Evaluation of fodder beets as a fall/winter grazing forage.

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

Evaluation of N, P, K, Se fertilization and Ag lime management and clipping intensity to develop best management practices for increased forage production and quality.

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.

Outreach Description

Forage-livestock system information developed and disseminated via several media and in-person methods for educating producers and other stakeholders with newly developed knowledge and information; web segments, Extension publications, shortcourses and seminars, Hay King Contest, experiment station field days and ranch visits, phone, email, and in-person requests.

Field survey about trace mineral levels related to livestock supplements to update supplemental requirement recommendations and save money for producers.

4. Impact Statement
5. Published Written Works

Referred Publications

Ates, S., Cicek, H., Gultekin, I., Yigezu, Y. A., Keser M., & Filley, S. 2018. Bio-economic analysis of dual-purpose management of winter cereals in high and low input production systems. *Field Crops Research*, 227: 56-66.

Daly, C., Halbleib, M., Hannaway, D.B., Eaton, L.M. 2018. Environmental Limitation Mapping of Potential Biomass Resources across the Conterminous United States. *Global Change Biology: Bioenergy* DOI: 10.1111/gcbb.12496.

- He, Feng, Kun Wang, Xianglin Li, and David B. Hannaway. 2018. Effects of precipitation and clipping intensity on net primary productivity and composition of *Leymus chinensis* in temperate grasslands. PLoS ONE PONE-D-17-14028R3.
- Misra, A. K. Kumar, S., Kumar, T.K., Ahmed, S., Palsaniya, D. R., Ghosh, P. K., Louhaichi, M., Sarker, A., Hassan, S. & Ates, S (2018). Nutrient intake and utilization in sheep fed opuntia [*Opuntia ficus-indica* (L.) Mill.] in combination with conventional green and dry fodders. Range Management and Agroforestry, 39: 97-102

Book chapters

- Hannaway, David B., Linda Brewer, Steve Fransen, Glenn Shewmaker, Shannon Williams, and Sarah Baker. 2018. Planning and Sowing Grasslands. Chapter 5, pp. 125-170. In: Improving Grassland and Pasture Management in Agriculture. Athole Marshall and Rosemary Collins, Eds. <http://dx.doi.org/10.19103/AS.2017.0024.10>

Bulletins and Extension

- Fery, Melissa, Maud Powell, and David B. Hannaway. 2019. Pasture and Grazing Management. Professional and Continuing Education Course. Oregon State Univ.
- Filley, Shelby. 2019. Grass Tetany: fast growing grass can mean problems. Oregon State Univ. Exten. Ser. <https://extension.oregonstate.edu/crop-production/pastures-forages/grass-tetany-fast-growing-grass-can-mean-problems>
- Moore, A., G. Pirelli, S. Filley, S. Fransen, D.Sullivan, M. Fery, and T. Thomson. 2019. Nutrient management for Pastures: Western Oregon and Western Washington. Oregon State Univ. Exten. Ser. EM 9224. <https://catalog.extension.oregonstate.edu/em9224>
- Roseberg, R.J., S. Norberg, and B.A. Charlton. 2018. Teff grass for forage: Nitrogen and irrigation requirements. PNW 709, Oregon State Univ. Extension Service.

6. Scientific and Outreach Oral Presentations

- Hannaway, D.B., L.J. Brewer, S. Ates, N.P. Anderson, G. Wang, S. Filley, C. Daly, M.D. Halbleib, C. Ringo, S. Monk, D.J. Moot, X. Yang, D.F. Chapman, and P. Sohn. 2018. Match Clover: Optimal selection of clover species. European Grassland Federation Conf., Cork, Ireland. 18-21 June.
- Hannaway, D., He, F., Moot, D., Yang, X., Mills, A., Smith, R., Teixeira, E., Shewmaker, G., Islam, A., Wang, G. 2018. Improving alfalfa (*Medicago sativa* L.) cultivar selection by GIS Mapping of Fall Dormancy and Winter Survival Index Classes and Modeling Seasonal and Annual Yield. 2nd World Alfalfa Congress, Cordoba, Argentina. 11-14 Nov. Abstract.
- Yang, X., Moot, D., Brown, H., Teixeira, E., Hung, T. Hannaway, D. 2018. Modelling Alfalfa (*Medicago sativa* L.) Phenological Development. 2nd World Alfalfa Congress, Cordoba, Argentina. 11-14 Nov. Abstract.
- Ates, S., Cicek, H., Ozcan G., and M. Tezel. 2018. Effect of nurse crop and seeding rate on the productivity and persistence of sainfoin in Central Anatolia ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD
- Ates, S., Louhaichi, M., Hassan, H., Cicek, H., Kassam, S., Qudratullah, S., Farhang, A.H. and Esmati, H. 2018. Effect of seeding rate on the yield of legume-cereal bi-crops in rainfed production systems of Afghanistan 5th International Conference on Sustainable Agriculture and Environment October 08-10, Hammamet, Tunisia.
- Ates, S., Keles, G., Demirci, U., Dogan, S., Ozcan, G. and Filley, S. (2018) The effects of

- forage-based and a concentrate feeding system on lamb production 12th World Conference on Animal Production July 5-8, Vancouver, Canada.
- Blair, S., Pirelli, G., Filley, S., Bohle, M., Davis, Z., Hall, J. and Wang G. (2018) Selenium and NPKS fertilization effects on alfalfa and grass production and quality in eastern Oregon. ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD
- Fan, Q., Blair, S., Hannaway, D. and Wang, G. (2018) Spring seeded annual forages differ in response to partial-season irrigation. ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD
- Fan, Q., Blair, S., Hannaway, D. and Wang, G. (2018) Summer seeded annual forages differ in response to partial-season irrigation. ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD
- Filley, S.J., Wang, G., Hall, J., Pirelli, G., Bohle, M., Ates, S. and Davis, T.Z. (2018) Selenium and fertiliser application schemes in hay fields, 27th European Grassland Federation General Meeting, 17th - 21st June Cork, Ireland
- Hannaway, D.B., Brewer, L.J., Ates, S., Anderson, N.P., Wang, G. Filley, S. Daly, C. Halbleib, M.D., Ringo, C., Monk, S., Moot, D.J., Yang, X., Chapman, D.F., and Sohn, P. 2018. MatchClover: web-based tool for matching clovers to climates, soils, and intended Uses, 27th European Grassland Federation General Meeting, 17th - 21st June Cork, Ireland
- Hannaway, D.B. 2018. Forage Production & Management lectures. Sichuan Agricultural University. “Foreign Expert” Program. Oct 7–30. Chengdu, Sichuan Province, China.
- Hannaway, D. B. 2018. Forage Production & Management lectures. Northwest Agriculture & Forestry University. “Foreign Expert” Program. Aug. 28–Sep. 6 and Nov. 4-9. Yangling, Shaanxi Province, China.
- Hannaway, David. 2018. MatchClover – Web Based Tools for Matching Clovers to Climates, Soils and Intended Uses. Invited Presentation to Tasmanian Institute of Agriculture, Launceston, Tasmania, Australia. May 9.
- Hannaway, David. 2018. MatchClover – Web Based Tools for Matching Clovers to Climates, Soils and Intended Uses. Plenary paper presented to Dairy NZ Workshop, Christchurch, New Zealand. Feb. 28.
- Slim, S., Harbeg, L., Hassan, S., Moyo, H.P., Ates, S. and Louhaichi, M. 2018. Yield and nutritive quality of *Hedysarum coronarium* across three different agro-climatic zones of northern Tunisia, 71st Annual Meeting of The Society for Range Management, Jan. 28 to Feb. 2, Reno, Nevada, US.

6. Collaborative grants

- Ates, S. Evaluation of seasonal yield, forage quality, and persistence of cool-season grass and legume species for sheep production systems in non-irrigated western Oregon pastures (ARF Grant)
- Ates, S. Milk and Forage Production from Mixed or Spatially Separated Simple and Diverse Pastures (ARF Grant)
- Ates, S. Milk Yield and Composition of Dairy Cows from Diversified Grass, Herb or Legume-based Summer Pastures (ODFA Grant)
- Ates, S. Fodder Beets as winter forage for cattle in eastern Oregon (W. SARE farmer rancher/researcher)

Filley, S. Prepared and received funding for a proposal for updating and improving the Forage Information System for the Forage-Livestock Systems Working Group. \$10,000.

Filley, S. "Evaluation of seasonal yield, forage quality, and persistence of cool-season grass and legume species for sheep production systems in non-irrigated western Oregon pastures." Funded for \$12,500 by the Agricultural Research Foundation, Oregon State University. PI: Serkan Ates; Cooperators: David Hannaway, Mary Smallman, Claudia Ingham, Shelby Filley, Gene Pirelli, and Jerry Hall.

Wang, G. Cover crops after forage spring triticale in eastern Oregon. \$12,500 from ARF.

Wang, G. Developing a fall-winter grazing system by using fodder beets. \$12,500 from ARF.

Wang, G. Irrigation and seeding date effects on winter grasses and forbs forage production and quality in eastern Oregon. \$17,434 from OBC.

South Dakota report 2018-2019
South Dakota State University

1. Impact Nugget:

Improving water use efficiency in alfalfa will greatly impact the production of the crop and the sustainability of the ecosystem on rangeland.

2. New Facilities and Equipment:

None

3. Unique Project Related Findings:

We recently identified an alfalfa (*Medicago sativa*) collection, River side (RS) that is naturized to the environments in the Grand River National Grassland in South Dakota, with a greater water use efficiency (WUE) under drought compared to other ten alfalfa accessions. To understand the mechanisms that may contribute to the higher WUE in RS, we examined physiological and morphological traits in comparison with Alfagraze (AF), a commercial variety with lower WUE under drought in a greenhouse. To introduce drought, plants were irrigated with the amount of water to compensate only for 50% of the transpirational water loss. Most physiological characterizations were done 28 days after stress treatment with the leaves and stems developed during the drought treatment. RS showed a greater reduction of transpirational water loss despite more stomates per unit area under drought. Both RS and AF showed a reduction of stomatal aperture under drought compared to respective well-watered plants but stomatal aperture in RS was smaller compared to AF regardless of irrigation status. Leaves of RS showed a more rapid accumulation of ABA, at 14 days vs at 28 days in AF under drought. RS also closed stomata more rapidly when treated with 10 μ M ABA. In addition, leaves of RS showed denser but shorter leaf hairs under drought. A correlation analysis points to a greater stomatal sensitivity to ABA in RS as a key factor contributing to its greater WUE under drought.

4. Accomplishment Summaries:

A higher water use efficiency in Riverside under drought is mostly due to its higher stomatal sensitivity to ABA compared to Alfagraze. 4. Impact Statements: One approach to improve water use efficiency in alfalfa under drought is to enhance stomatal sensitivity to ABA.

5. Published Written Works *Cite them with CSSA, ASA references format*

None. (A manuscript is prepared and will be submitted shortly after coauthors' editing.)

6. Scientific and Outreach Presentations

None

7. Collaborative Grants

None

8. Graduate students

Surbhi Gupta, MS, expected graduation date: July 2020; Tentative thesis title: Stomatal density and stomatal behavior in water use efficiency in alfalfa

Texas 2018-2019 report 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.

2. New Facilities and Equipment

3. 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.

Accomplishment Summaries

During 2018-2019, 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. A summary of all publications from 2018-2019 is included at the end of this document.

4. Impact Statements

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 will be commercialized by Grasslands Innivation, NZ, and we are in the final stage of developing 2 cultivars of orchardgrass, and 2 cultivars of perennial ryegrass.

Issue: Sorghum is more drought tolerant than corn; therefore, sorghum is a more efficient crop in semi-arid regions. There is a paucity of information on the nutritive value of sorghum silage, compared to corn silage.

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 land owners.

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. Warm-season perennial grasses are the mainstay of livestock production in Texas; however, these are typically lesser in quality than cool-season grasses.

Action: We have generated data on relatively new warm-season annual forage, teff, for the forage producers in the Rolling Plains of Texas.

5. Published Written Works

Refereed Journal Articles

- Araújo, A.R., N.M. Rodriguez, M.C.P. Rogério, I. Borges, E.O.S. Saliba, S.A. Santos, R.C.F.F. Pompeu, F.E.P. Fernandes, J.P. Monteiro, and J.P. Muir. 2019. Nutritional evaluation and productivity of supplemented sheep grazing in semiarid rangeland of northeastern Brazil. *Tropical animal health and production*. 51:957-966.
- Belesky, D.P., Halvorson, J.J., Ruckle, J.M., Malinowski, D.P., Mata-Padrino, D.J. 2019. Designed and naturalized sward response to management: I. Patterns of herbage production. *Annals of Applied Biology* 175, 42-53. <https://doi.org/10.1111/aab.12512>
- Farthing, T.S., J.P. Muir, A.D. Falk, and D. Murray. 2018. Efficacy of Seven Invasive-Bermudagrass Removal Strategies in Three Texas Ecoregions. *Ecological Restoration*. 36:306-314.
- Foster, J.L. 2019. The arboreal legume dilemma: adaptation and weediness. *Legume Perspectives*. 17:30-32.
- Foster, J.L., M.E. Thomas-Moen, K.C. McCuiston, L.A. Redmon, and R.W. Jessup. 2019. Potential of ensiling sorghum without grain pre-treated with enzymes or bacterial inoculants. *Crop Sci*. doi:10.2135/cropsci2019
- Grichar, W.J., and J.L. Foster. 2019. Can nicosulfuron plus metsulfuron combinations effectively control or suppress King Ranch bluestem? *Crop, Forage, and Turfgrass Mngmt*. doi:10.2134/cftm2018.09.0069
- Kimura, E., S. Fransen, H. Collins, B. Stanton, A. Himes, J. Smith, S. Guy, and W. Johnston. 2018. Effect of intercropping hybrid poplar and switchgrass on biomass yield, forage quality, and land use efficiency for bioenergy production. *Biomass and Bioenergy*. 111:31-38.
- Lewis, K.L., J.L. Foster, and F.M. Hons. 2019. Lipid-extracted algae as a soil amendment can increase soil salinization and reduce forage growth. *Sustainability*. 11:1-18. doi:10.3390/su11071946
- Malinowski, D.P., Belesky, D.P. 2019. Epichloë (formerly Neotyphodium) fungal endophytes increase adaptation of cool-season perennial grasses to environmental stresses. *Acta Agrobotanica* 72(2):1767. <https://doi.org/10.5586/aa.1767>.
- Malinowski, D.P., Pinchak, W.E., Pitta, D., Min, B.R. 2018. Solar radiation affects bloat potential of wheat forage. *Acta Agrobotanica* 71(4):1754. <https://doi.org/10.5586/aa.1754>
- Malinowski, D.P., Rudd, J.C., Pinchak, W.E., Baker, J. 2018. Determining morphological traits for selecting wheat (*Triticum aestivum* L.) with improved early-season forage production. *J. Advances in Agriculture* 9:1508-1530.
- Muir, J.P., M.V. Ferreira Santos, M.V. da Cunha, J.C.B. Dubeux Júnior, M. de Andrade Lira, Jr., R.T. de Almeida Souza, and T.C. de Souza. 2019. Value of endemic legumes for livestock production on Caatinga rangelands. *Brazilian Journal of Agricultural Sciences*. 14.1-12.

- Muir, J.P., T.H. Terrill, J.A. Mosjidis, J.M. Luginbuhl, J.E. Miller, J.M. Burke, and S.W. Coleman. 2018. Harvest regimen changes sericea lespedeza condensed tannin, fiber and protein concentrations. *Grassland Science*. 64:137-144.
- Muir, J.P., W.D. Pitman, F.S. Smith, J. Lloyd-Reilley, and R.A. Shadow. 2019. Challenges to developing native legume seed supplies: the Texas experience as a case study. *Native Plants Journal*. 19: 224-238.
- Mullenix, M.K., and F.M. Rouquette, Jr. 2018. Cool-season annual grasses or grass-clover management options for extending the fall-winter-early spring grazing season for beef cattle. *The Professional Animal Scientist*. 34:231-239.
- Neely, C.B., F. Rouquette, C.L. Morgan, G.R. Smith, F.M. Hons, and W.L. Rooney. 2018. Integrating legumes as cover crops and intercrops into grain sorghum production systems. *Agronomy Journal*. 110:1363-1378.
- Rogério, M.C.P., E.C. Martins, L. Shiotsuki, R.C.F.F. Pompeu, J.P. Muir, A.R. Araújo, D. de Sousa Oliveira, J.L.L. Magalhães, W.É. Campos, O. Facó, and A.A. Alves. 2019. Economic viability of finishing lambs in the feedlot using bovine cheese whey as a dietary ingredient. *Small ruminant research*. 170:131-136.
- Rouquette, F.M., E. van Santen, and G.R. Smith. 2019. Long-term forage and cow-calf relationships for bermudagrass overseeded with arrowleaf clover or annual ryegrass managed at different stocking rates. *Crop Science*. 58:1426-1439.
- Sawyer, J., B.D. Lambert, J.P. Muir, J.K. Apple, J.J. Ball, and R.N. Cauble. 2019. Fresh Ham Chop Characteristics Cooked to Various Internal Endpoint Temperatures. *Meat and Muscle Biology*. 2:114-114.
- Schwartz, R.C., A.J. Schlegel, J.M. Bell, R.L. Baumhardt, and S.R. Evett. 2019. Contrasting tillage effects on stored soil water, infiltration and evapotranspiration fluxes in a dryland rotation at two locations. *Soil and Tillage Res*. 190:157-174.
- Singh, R.D., J. Banerjee, S. Sasmal, J. Muir, and A. Arora. 2018. High xylan recovery using two stage alkali pre-treatment process from high lignin biomass and its valorisation to xylooligosaccharides of low degree of polymerization. *Bioresource technology*. 256:110-117.
- Tontini, J.F., C.H.E.C. Poli, V. da Silva Hampel, N.M. Fajardo, A.A. Martins, A.P. Minho, and J.P. Muir. 2019. Dispersal and concentration of sheep gastrointestinal nematode larvae on tropical pastures. *Small Ruminant Research*. 174:62-68.
- White, J.A., J.P. Muir, and B.D. Lambert. 2018. Overseeding Cool-Season Annual Legumes and Grasses into Dormant 'Tifton 85' Bermudagrass for Forage and Biomass. *Crop Sci*. 58:964-971.
- Wynne, K., C. Adams, C. Neely, P. DeLaune, E. Kimura, and S. Thapa. 2019. Canola Emergence and Early Growth Were Not Affected by Allelopathic Properties of Wheat Residue. *Agrosystems, Geosciences & Environment*. 2:180058.
- Woli, P., F.M. Rouquette, and C.R. Long. 2019. Investigating DSSAT: Bermudagrass Response to Nitrogen as Influenced by Soil and Climate. *Agronomy Journal*. 111:1741-1751.
- Woli, P., F.M. Rouquette, G.R. Smith, C.R. Long, and L.R. Nelson. 2019. Simulating Winter Wheat Forage Production in the Southern United States Using a Forage Wheat Model. *Agronomy Journal*. 111:1141-1154.
- Xu, Y., J.L. Foster, J.P. Muir, B.L. Burson, and R.W. Jessup. 2018. Succinic acid production across candidate lignocellulosic biorefinery feedstocks. *Amer. J. Plant Sci*. doi: 10.4236/ajps.2018.911155

Book Chapters

- Corriher-Olson, V., L.A. Redmon, and M. Rouquette, Jr. 2019. Weed Control in Pastures. In: M. Rouquette and G.E. Aiken, editors, Management Strategies for Sustainable Cattle Production in Southern Pastures. Elsevier.
- Jennings, J., and J.L. Foster. 2019. Legume Structure and Morphology. In: D. Redfearn, et al., editors, Forages: The Science of Grassland Agriculture. Vol. II, 7th ed., Wiley-Blackwell, Hoboken, NJ.
- Rouquette, Jr., M., V. Corriher-Olson, and G.R. Smith. 2019. Management Strategies for Pastures and Beef Cattle in the Middle South: The I-20 Corridor. In: M. Rouquette and G.E. Aiken, editors, Management Strategies for Sustainable Cattle Production in Southern Pastures. Elsevier.

Symposium Proceedings

- Muir, J.P., F.S. Forrest, J. Brady, J.C. Dubeux, and W.D. Pitman. 2018. Domesticating Shrubby Native Legumes for Pastures and Natural Grasslands. Proceedings in Breeding Grasses and Protein Crops in the Era of Genomics. Springer.
- Norris, A.B., L.O. Tedeschi, K.D. Casey, J.C.B. Dubeux, J.L. Foster, J.P. Muir, and W.E. Pinchak. 2018. Quebracho (*Schinopsis balansae*) extract in beef cattle fed high-roughage total mixed ration affects manure gas emissions. International Symposium on the Nutrition of Herbivores, Clermont-Ferrand, France, Sept. 2-6.

Abstracts

- Falk, A.D., K.A. Pawelek, F.S. Smith, J.P. Muir, J.L. Foster, L. Herzberger, T. Farthing, and W.P. Kuvlesky, Jr. 2018. Bermudagrass control and restoration of native prairie for Northern Bobwhites. Texas Section Society for Range Management, Lubbock, TX, Oct. 11-12. (Abstr.)
- Flynn, K., P.W. Tracy, D. Liptzin, G.M. Bean, S. Cappellazzi, M. Cope, K.L. Hoegenauer, E. Rieke, C. Norris, C.W. Honeycutt, C.L.S. Morgan, and NAPSHM Collaborators. 2019. Slakes smartphone application to quantify aggregate stability: Performance across a range of soil types and managements. ASA-CSSA-SSSA 2019 International Meetings, Baltimore, MD, Nov. 10-13. (Abstr.)
- Garcia, T.J., J.A. Brady, K.A. Guay, J.P. Muir, and W.B. Smith. 2019. Reduce Reuse ReRumen: Variability in nutritive value of paunch manure. Journal of Animal Science. 97:14-14.
- Hoegenauer, K.L., G.M. Bean, S. Cappellazzi, M. Cope, D. Liptzin, C. Norris, E. Reike, P.W. Tracy, K. Flynn, C.W. Honeycutt, J.A. Howe, C.L.S. Morgan, and NAPSHM Collaborators. 2019. Comparing aggregate stability analyses to evaluate soil health across North America. ASA-CSSA-SSSA 2019 International Meetings, Baltimore, MD, Nov. 10-13. (Abstr.)
- Maeda, A., J. Landivar, J.L. Foster, A. Ashpure, J. Yeom, M. Maeda, A. Chang, and J. Jung. 2018. Evaluation and quantification of environmental sustainability of different tillage treatments in South Texas. ASA-CSSA-SSSA 2018 International Meetings, Baltimore, MD, Nov. 4-7. (Abstr.)
- Morgan, C.L.S., P.W. Tracy, G.M. Bean, M. Cope, S. Cappellazzi, K.L. Hoegenauer, D. Liptzin, C. Norris, E. Rieke, NAPSHM Collaborators, and C.W. Honeycutt. 2019. Measurements to assess soil health indicators and link them to soil ecosystem services. ASA-CSSA-SSSA 2019 International Meetings, Baltimore, MD, Nov. 10-13. (Abstr.)
- Muir, J.P., 2018. Livestock systems forage research: agronomy in and beyond the paddock. Journal of Animal Science. 96:213-214.

- Norris, A.B., L.O. Tedeschi, J.L. Foster, J.P. Muir, and B.E. Pinchak. 2019. Effects of feeding different levels of Quebracho (*Schinopsis balansae*) in a high-roughage total mixed ration on seasonal manure gas emissions. American Society of Animal Science-Canadian Society of Animal Science Annual Meeting, Austin, TX, Jul. 8-11. (Abstr.)
- Norris, A.B., L.O. Tedeschi, J.L. Foster, J.P. Muir, and B.E. Pinchak. 2019. Influence of Quebracho (*Schinopsis balansae*) tannin extract fed at differing rates in a high-roughage diet on energy partitioning in beef steers. American Society of Animal Science-Canadian Society of Animal Science Annual Meeting, Austin, TX, Jul. 8-11. (Abstr.)
- Norris, A.B., L.O. Tedeschi, K.D. Casey, J.C.B. Dubeux, J.L. Foster, J.P. Muir, and W.E. Pinchak. 2018. Effects of feeding different levels of quebracho (*Schinopsis balansae*) extract in a high-roughage total mixed ration on manure gas emissions. ASAS Southern Section Meeting, Fort Worth, TX, Feb. 3-6. (Abstr.)
- Norris, A.B., W.L. Crossland, L.O. Tedeschi, J.L. Foster, J.P. Muir, and W.E. Pinchak. 2018. Effect of differing rates of Quebracho (*Schinopsis blansae*) extract fed in a limit fed high roughage TMR upon digestibility and nitrogen balance. American Society of Animal Science-Canadian Society of Animal Science Annual Meeting, Vancouver, Canada, Jul. 8-12. (Abstr.)
- O'Daniel, S.E., D.G. Riley, D.A. Neuendorff, T.D. Forbes, J.P. Banta, T.H. Welsh Jr, F.M. Rouquette, and R.D. Randel. 2018. Comparison of Three Methods of Determining Feed Efficiency on Productivity of Brahman Heifers. *Journal of Animal Science*. 96:42-42.

Extension Publications

- Corriher-Olson, V., and J.L. Foster. Forage Management Strategies for Drought Conditions. SCS-2018-17.
- Corriher-Olson, V., and J.P. Banta. 2019 Herbicide and Insecticide Cost Per Acre Spreadsheet. SCS-2019-03.

Popular Articles

- Allen, Lindsay and V. Corriher-Olson. It Doesn't Get Better With Age. *Gulf Coast Cattleman's*. February 2018
- Allen, Lindsay and V. Corriher-Olson. When It Freezes Over. *Gulf Coast Cattleman's*. 2018.
- Allen, Lindsay and V. Corriher-Olson. Less is More When Grazing. *Gulf Coast Cattleman's*. August 2018.
- Corriher-Olson, V.. Minimize winter hay-feeding losses. *Hay and Forage Grower*. October 31, 2018
- Corriher-Olson, V. Managing Grassy Weeds in a Grass Pasture or Hay Meadow. *The Cattleman*. February 2018.
- Corriher-Olson, V. Planning next year's forages. *Progressive Forage*. January 1, 2018.
- Corriher-Olson, V. Hay Production, stockpiled forage and baleage. *Progressive Forage*. January 30, 2018.
- Corriher-Olson, V. Does a New Year Mean a New Pasture/Hay Meadow? *Gulf Coast Cattleman*. February 2019.
- Fannin, Blair and V. Corriher-Olson. Yaupon presents problems for range pasture management. *AgriLife Today*. June 2018. (reprinted Angus Beef Bulletin)
- Ledbetter, K. and J. Bell. Wheat 'gain or grain' decision time is now in the Texas High Plains. Feb 2019.

Ledbetter, K., E. Bynum and J. Bell. AgriLife Extension study: Forage sorghum silage viable option with sugarcane aphid control. AgriLife Today. 2/10/2019

Ledbetter, K. and J. Bell. Forage sorghum field day demonstrates high yielding varieties, sugarcane update. Sept 2018.

Mills, B. and V. Corriher-Olson. Stockpiling Bermudagrass. Gulf Coast Cattleman's. 2018

Mills, B. and V. Corriher-Olson. Tackling Toxic Weeds: An equal opportunity problem, weeds can show up in grass hay just as easily as in alfalfa. myFARMLIFE.com

Russell, A. and V. Corriher-Olson. Low temperatures will help some producers, cause minimal damage for others. AgriLife Today. January 8, 2018. (reprinted The Cattleman)

Russell, A. and V. Corriher-Olson. East Texas Pasture Management Program in Overton Feb. 23. AgriLife Today. January 2018.

Russell, A. and V. Corriher-Olson. Win the war against weeds in warm season pastures. AgriLife Today. February 12, 2018. (reprinted AgFax and The Cattleman)

Russell, A. and V. Corriher-Olson. AgriLife Expert: Gopher control, tricky, worth effort. AgriLife Today. April 2018. (reprinted Waco Tribune Herald, The Cattleman)

Russell, A. and V. Corriher-Olson. Texas Crop and Weather Report—April 17, 2018. AgriLife Today. April 17, 2018. (reprinted The Cattleman)

Russell, A. and V. Corriher-Olson. Hay producers should hold fertilizer until temps rise. AgriLife Today. April 2018. (reprinted AgFax; My Plainview;)

Russell, A. and V. Corriher-Olson. AgriLife Extension expert talks Bermudagrass 101. AgriLife Today. May 30, 2018. (Reprinted: Land & Livestock Post and The Cattleman)

Russell, A. and V. Corriher-Olson. Winter pasture, stockpiled forage workshop to cover options amid drought. AgriLife Today. July 2018. (reprinted Gulf Coast Cattleman)

Russell, A. and V. Corriher-Olson. Texas Crop and Weather Report—September 18, 2018. AgriLife Today. September 2018. (reprinted The Cattleman)

Russell, A. and V. Corriher-Olson. Producers, homeowners battling armyworms. AgriLife Today. September 2018. (reprinted AgFax; NTXE News)

Russell, A. and V. Corriher-Olson. Expert: Few options to salvage late-season hay amid wet weather. AgriLife Today. November 7, 2018. (reprinted Drovers, The Cattleman)

Russell, Adam and V. Corriher-Olson. Texas Crop and Weather Report—April 23, 2019. AgriLife Today. April 2019. (reprinted AgFax, The Cattleman)

6. Scientific Outreach Presentations

Bell, J.M., 2019. The Impact of Limited Water on Silage Production. University of Arizona 6th Annual New Technologies Workshop for Arizona Field Crops. Maricopa, AZ. 6/12/2019

Bell, J.M., 2019. Quality Corn Silage. NMSU Southwest Hay and Forage Conference. Ruidoso, NM. 1/24/2019

Bell, J.M. 2018. Sorghum Silages. Texas A&M AgriLife Dublin Winter Silage Program. Dublin, Texas. 12/18/2018

Bell, J., T. McCollum, E. Bynum, R. Schnell, D. Pietsch, P. Sirmon, B. Finch and C. Naylor. 2018. 2018 Texas Panhandle Forage Sorghum Silage Trial.

Foster, J.L. 2019. Soil Health in South Texas. Soil Health Workshop. Natural Resources Conservation Service, Victoria, TX, Apr. 23-24, 2019.

Foster, J.L. 2018. Grazing Strategies. 2018. Texas A&M AgriLife Extension Brazoria and Galveston County Forage Series. Angleton, TX. Aug. 30, 2018.

- Foster, J.L. 2019. Resilience in Forages and Grazinglands. Texas Organic Farmers and Gardeners Association. Corpus Christi, TX, Feb. 16, 2019.
- Foster, J.L. 2019. Forages of South Texas Update. Texas Pasture and Forage Work Group. College Station, TX, Jan. 7, 2019.
- Foster, J.L. 2019. Forage Research Discussion Panel. Texas Pasture and Forage Work Group. College Station, TX, Aug. 8, 2018.
- Foster, J.L. 2018. UAS Based Characterization of Forages and Pasture Management. Texas A&M UAS Working Group Annual Meeting. Jan. 9, 2018.
- Foster, J.L. 2019. Tillage Systems Effect on Organic Matter, Infiltration, and Water Holding Capacity. Nueces County Field Crop Tour Continuing Education Unit Event. Texas A&M AgriLife Extension of Nueces County. Jun. 5, 2019.
- Foster, J.L. 2019. Forages and Beekeeping. Coastal Bend Beekeepers Association. Corpus Christi, TX, May 2, 2019.
- Foster, J.L. 2019. Field Day: Converting bermudagrass to native grassland to benefit bobwhite quail. Hosted and planned by the Texas A&M AgriLife Research Station-Beeville. Apr. 30, 2019.
- Foster, J.L. 2019. Women in Plant Science. 2019. Girl Scouts of Greater South Texas. Bishop, TX, Apr. 8, 2019.
- Foster, J.L. 2018. Research and Management: Old World Bluestems. 2018. Carr Ranch Gathering. Texas A&M AgriLife Extension of Wilson County. Floresville, TX, Oct. 19, 2018.
- Foster, J.L. 2018. Tillage Systems Research Update. Texas A&M AgriLife Extension of Nueces and San Patricio Counties. Corpus Christi, TX, Jan. 11, 2018.
- Olson, V.C. Blackland Income Growth. Grass species adapted to Blackland clay soils. Waco, Tx. Jan 10, 2018.
- Olson, V.C. Blackland Income Growth. Fertilizer Options. Waco, TX. Jan. 10, 2018
- Olson, V.C. East Texas Pasture Management. Effective weed control with weed identification, proper timing and herbicide selection. Overton, TX. February 23, 2018.
- Olson, V.C. Texas Southwest Cattle Raisers Association. Grazing Management Strategies. Ft. Worth, TX. March 24, 2018.
- Olson, V.C. Ranch Management University. Hay Production. College Station, TX. April 3, 2018.
- Olson, V.C. Ranch Management University. Legumes. College Station, TX. April 3, 2018.
- Olson, V.C. NRCS Agronomist Meeting. Legumes for Central and East Texas. Stephenville, TX. May 2, 2018.
- Olson, V.C. Texas Soil and Water Conservation. Soil health with forages. Palestine, TX. May 9, 2018.
- Olson, V.C. O.D. Butler Field Day. Brush Control. Franklin, TX. May 17, 2018.
- Olson, V.C. Surface Mine Reclamation Workshop. Forage selections, establishment, and management. College Station, TX. October 4, 2018.
- Olson, V.C. Northeast Texas Fall Dairy Conference. Weed control, herbicides and potential herbicide residual in manure. Sulphur Springs, TX. October 31, 2018.
- Olson, V.C. Blackland Income Growth. Bermudagrass decline. Waco, TX. Jan. 15, 2019.
- Ruppert, D., N. Haile, J. Riley, A. Maeda, and J.L. Foster. 2018. Benefits and Challenges of Soil Health Management in Row Cropping. Del Mar Center for Economic Development. Corpus Christi, TX, Jan. 25, 2018.

7. Collaborative Grants between Stations and Members Awarded in 2017

- Adams, C., B. Pinchack, E. Kimura, J. Bell, A. Somenahally, and S. Park. Introducing organic to producers of grain-only and pasture-grain wheat cropping systems of northern Texas. 2018-2021.
- Banta, J., V.C. Olson, J. Foster, R. Noland and R. Redden. Prussic Acid Poisoning Risk of Johnsongrass Regrowth. Texas A&M Animal Science Department Mini Grant: Extension Enhancement and Scholarship. 2019. (Total awarded: \$7,970)
- Bell, N.L., J. Foster, V. Olson and J. Banta. 2017-2020. TExAS Scholar Program: Teaching with Experiential learning in Animal Science. USDA/NIFA/AFRI ELI. (Collaborator). \$299,856.
- Bellows, B., J.P. Muir, and J. Brady. 2017. NLGCA-NIFA. Capacity Building for Soil-Plant-Animal Interaction Research and Education. 2018-2020. Total awarded: \$300,000.

Texas report 2018-2019
Texas Tech University

1. Impact Nugget:

Interseeding alfalfa can improve grazed grasslands by adding a high-protein forage species and increasing the system productivity, but runs the risk of soil water depletion owing to its relatively high consumptive use of water. The upright-type cultivars, ‘NuMex Bill Melton’ and ‘WL440HQ’ established better than the prostrate grazing-type blend ‘Falcata-Rhizoma’. Therefore, improved hay-type cultivars targeted for the Southern High Plains would be a viable choice for interseeding into native grassland. Interseeding alfalfa at low density into native grasses on the Texas High Plains can enrich the crude protein and digestible energy concentrations and forage yield of the pastures with minimal exacerbation of soil water depletion.

2. New Facilities and Equipment.

A site-specific calibration of the Delta-T PS2/6 capacitance probe was carried out to attain research-quality accuracy in measurement of soil water. The calibration technique was published by Dhakal et al., (2019). We produced equipment for measuring methane emissions from cattle while they graze. We will be measuring the effect of including alfalfa in mixture with WW-B.Dahl old world bluestem receiving no N fertilizer vs. bluestem growing alone and receiving 65 kg/ha of N fertilizer on enteric methane emission from the cattle.

3. Unique Project Related Findings.

1. Interseeding alfalfa into existing stands of native short grasses was demonstrated to be a low-cost, water-efficient method of increasing yield and forage quality of the grassland with negligible effect on soil water depletion. We have thus extended the use of alfalfa for summer grazing in mixtures with introduced and native grass stands. These advancements provide excellent options for farmers to convert irrigated cropland to ultra-low irrigation or rainfed grassland as irrigation becomes more limited for annual row crops owing to the depletion of the Ogallala Aquifer.

2. We have successfully calibrated the ALMANAC and APSIM models for predicting growth of WW-B.Dahl old world bluestem. We also demonstrated the ability of ALMANAC to simulate bluestem growth under varying levels of irrigation.

4. Accomplishment Summaries.

The overall aim is to help irrigated row-crop producers in the Texas High Plains adapt to declining water supplies by integrating grazing into the cropping system. Our strategy is to develop forage management systems that diversify agricultural land use away from continuous row-crop monoculture receiving high irrigation input toward profitable, low-water-use grazing systems. We have demonstrated three practices involving the legumes alfalfa in mixture with introduced old world bluestem, with tall wheatgrass as a protein bank, and most recently with native short grasses as ways to boost animal productivity with minimal or no irrigation. Advances were made in improving the ALMANAC model for predicting forage growth under varying water supplies.

5. Impact Statements.

WW-B.Dahl Old World bluestem provides a very desirable warm-season perennial grass as the backbone of a beef stocker grazing system requiring very low water input from irrigation (5 to 9

inches per year), which is one-third to one-half of that required to produce cotton and one-fourth to one-third of that required to produce corn. Our modeling work will lead to a decision aid tool for producers to most profitably allocate a dwindling water supply among fields while maintaining profitability.

Alfalfa shows great promise to improve low-irrigation pastures in the Texas High Plains both in mixture with the warm-season grass WW-B.Dahl, the cool-season grass tall wheatgrass, with a mixture of native short grasses in rainfed conditions. This is despite the reputation of alfalfa as a highly water-consumptive crop.

The development of a calibrated ALMANAC model allows its deployment for use in irrigation scheduling and prediction of pasture carrying capacity of WW-B.Dahl old world bluestem, which is the most promising warm-season grass to grow for beef cattle as producers transition from intensively irrigated row crops to ultra-low irrigation rainfed production as the local groundwater recedes.

6. Published Written Works.

Refereed Journal Articles

- Lindsay, K.R., M.P. Popp, C.P. West, A.J. Ashworth, A.C. Rocateli, R. Farris, V.G. Kakani, F.B. Fritschi, V.S. Green, M.W. Alison, M.J. Maw, L. Acosta-Gamboa. 2018. Harvest time effects on switchgrass moisture content, nutrient concentration, yield, and profitability. *Biomass Bioenergy* 108:74-89. doi:10.1016/j.biombioe.2017.09.017
- Cano, A., A. Núñez, V. Acosta-Martinez, M. Schipanski, R. Ghimire, C. Rice, and C. West. 2018. Current knowledge and future research directions to link soil health and water conservation in the Ogallala Aquifer region. *Geoderma* 328:109-118. doi:10.1016/j.geoderma.2018.04.027
- Bhandari, Krishna B., C.P. West, and S.D. Longing. 2018. Fly densities on cattle grazing 'WW-B. Dahl' old world bluestem pasture systems. *Texas J. Agric. Nat. Res.* 31:T1-T5.
- Bhandari, K.B., C.P. West, S.D. Longing, C.P. Brown, and P.E. Green. 2018. Comparison of arthropod communities among different forage types on the Texas High Plains using pitfall traps. *Crop Forage Turfgrass Management* Vol. 4(2):180005. doi:10.2134/cftm2018.01.0005.
- West, C.P., and L.L. Baxter. 2018. Water footprint of beef production on Texas High Plains pasture. *Water International* 43:887-891. doi:10.1080/02508060.2018.1515574
- Bhandari, K.B., C.P. West, V. Acosta-Martinez, J. Cotton, and A. Cano. 2018. Soil microbial communities, enzyme activities, and total carbon and nitrogen as affected by diverse grasses and grass-alfalfa in pastures. *Appl. Soil Ecol.* 132:179-186. doi:10.1016/j.apsoil.2018.09.002 (I.F. 3.2)
- Bhandari, K.B., C.P. West, S.D. Longing, C.P. Brown, P.E. Green, and E. Barkowsky. 2018. Pollinator abundances in semi-arid pastures as affected by forage species. *Crop Sci.* 58:2665-2671. doi:10.2135/cropsci2018.06.0393
- Bhandari, K.B., C.P. West, and S.D. Longing. 2018. Communities of canopy-dwelling arthropods in response to diverse forages. *Agric. Environ. Letters* 3(1):180037 (online) doi:10.2134/aerl2018.07.0037
- Rudnick, D.R., S. Irmak, C.P. West, I. Kisekka, T.H. Marek, J.P. Schneekloth, D.M. McCallister, V. Sharma, K. Djaman, J. Aguilar, J.L. Chávez, M. Schipanski, D.H. Rogers, and A. Schlegel. 2018. Deficit irrigation management of maize above the High Plains Aquifer: A review. *J. Am. Water Res. Asso.* 55:38-55.

Other Creative Works

- West, C.P., and C.J. Nelson. 2018. Grassland ecosystems and their management. In M. Collins, C.J. Nelson, K.J. Moore, and R.F Barnes (eds.) Forages: An introduction to grassland agriculture. Vol. I. 7th edition. John Wiley & Sons, Hoboken, NJ. pp. 357-371.
- Chen, Y., D. McCallister, P. Johnson, L. Baxter, and C. West. 2018. Economic evaluation of integrating legume and beef production on low-water input systems. Southern Agricultural Economics Association Annual Meeting, 2-6 February, Jacksonville, Florida.

Poster Presentations and Abstracts

- Bernadt, T., D. Brown, D. Dubois, B. Fuchs, W. Hargrove, S. Hermitte, A. Kremen, M. Shafer, C. Steele, R. Steele, C. Turner, and C. West. 2018. Regional drought early warning, impact, and assessment for water and agriculture in the Rio Grande basin, 2016-2017. Annual Meeting American Meteorological Society, Austin, TX.
- Chen, Y., D. McCallister, C.P. West, L.L. Baxter, C.P. Brown, and P.E. Green. 2018. Economic evaluation of integrating legume and beef production on low-water-input systems. Southern Section of Am. Soc. Agric. Econ. 2-6 February, Jacksonville, FL.
- Bhandari, K., C.P. West, S.D. Longing, and V. Acosta-Martinez. 2018. Insect and soil microbial community size in native and introduced pastures. Abstract for International Aridlands Conference, 13-14 August, Lubbock, TX.
- Dhakal, M., and C.P. West. 2018. Can interseeded alfalfa deplete water in semiarid grassland? Abstract for International Aridlands Conference, 13-14 August, Lubbock, TX.
- Kharel, Geeta, S.K. Deb, and C.P. West. 2018. Evaluation of different models for quantifying water retention and thermal properties of semi-arid pasture soils land. Abstract for International Aridlands Conference, 13-14 August, Lubbock, TX.
- Otuya, R.K., L.C. Slaughter, C. West, V. Acosta-Martinez, and S.K. Deb. 2018. Effects of compost manure on soil microbial communities and soil health in a semi-arid improved pasture ecosystem. Abstract for International Aridlands Conference, 13-14 August, Lubbock, TX.
- Hughes, Paxton, H. Decker, S. Deb, L. Slaughter, and C. West. 2018. Greenhouse gas emissions from soils of semi-arid pastures: Response to legume presence. Poster for SARE James Harrison Hill, Sr. Young Scholar Enhancement Grant. August meeting of USDA-Southern SARE Administrative Council meeting. <http://www.southernsare.org/Grants/Types-of-Grants/James-Harrison-Hill-Sr.-Young-Scholar-Enhancement-Grant-Program/2018-Young-Scholar-Enhancement-Grant-Projects>.
- Bhattarai, B. S. Singh, C.P. West, G.L. Ritchie, and C. Trostle 2018. Forage production potential of sorghum, pearl millet and corn under different irrigation regimes. 5-8 Nov. In Annual meetings abstracts [CD-ROM]. ASA and CSSA., Madison, WI. Poster.
- Dhakal, M., and C.P. West. 2018. Establishment and persistence of alfalfa no-till interseeded into semiarid native grassland. 5-8 Nov. In Annual meetings abstracts [CD-ROM]. ASA and CSSA., Madison, WI. Oral.
- Dhakal, Madhav, and C.P. West. 2018. Can interseeded alfalfa deplete water in semi-arid grassland? 5-8 Nov. In Annual meetings abstracts [CD-ROM]. ASA and CSSA., Madison, WI. Poster.
- Bhandari, Krishna, C.P. West, S.B Longing, V. Acosta-Martinez, and D. Klein. 2018. Arthropod and soil microbial communities in forage-livestock systems. 5-8 Nov. In Annual meetings abstracts [CD-ROM]. ASA and CSSA., Madison, WI. Oral.

- Xiong, Victoria, C.P. West, and J.R. Kiniry. 2018. Applying digital image analysis to simulate growth of old world bluestem with ALMANAC. 5-8 Nov. ASA and CSSA, In Annual meetings abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.
- Bhandari, Krishna, C.P. West, V. Acosta-Martinez, and J. Cotton. 2018. Soil health indicators as affected by diverse forage species and mixtures in semi-arid pastures. In Annual meeting of Ogallala Water CAP project. Nov. 29-30, Santa Fe, NM.
- Longing, S.D., C. Jewett, B. Rendon, S. Discua Duarte, R. Cox, C. McKenney, N. McIntyre, and C.P. West. 2018. An assessment of bee richness and community structure across different agroecosystems on the Southern High Plains (Texas, USA). XXV International Congress of Entomology. Orlando, FL.
- Longing, S.D., C.P. West, N. McIntyre, R. Cox, and C. McKenney. 2018. Demonstrations of pollinator habitat and a framework for regional implementation in the U.S. Southern High Plains. SWCS International Annual Conference, Albuquerque, NM. Soil Water Conservation Society.

Popular Articles

- West, C., D. Porter, B. Guerrero, V. Uddameri, J. Bordovsky, J. Bell, and J. Tracy. 2018. Texas. Ogallala Aquifer Summit White Papers. April 9-10, Garden City, Kansas. <http://ogallalawater.org/ogallala-summit-white-papers/>

7. Scientific and Outreach Oral Presentations

- West, C.P. 2018. Water footprint of stocker beef production. Annual meeting of the American Society of Animal Science. July 11, Vancouver, BC.
- West, C.P. 2018. Advances in irrigation technology for water conservation in the U.S. High Plains. Third International Conference on Water Resources. 27-28 September. Tarija, Bolivia.
- West, C.P., and E.W. Hellman. 2018. Irrigation scheduling of vineyard. Third International Conference on Water Resources. 27-28 September. Tarija, Bolivia.
- West, C.P. 2018. Role of grasslands and cattle in conversion of irrigated cropland to dryland agriculture. Leu Distinguished Lecture Series, Nebraska Center for Grassland Studies. Nov. 12., Lincoln, NE.

8. Fund leveraging, specifically, collaborative grants between stations and members.

Long-term agro-ecosystems research and adoption in the Texas Southern High Plains. USDA Southern SARE Large Systems Research program. \$100,000 per year from 2014-2018. Lead PI.

Sustaining agriculture through adaptive management resilient to a declining Ogallala Aquifer and changing climate. Meagan Schipanski (CSU, Lead PI) and 12 co-PDs including C.P. West. USDA-NIFA-AFRI CAP. \$10,000,000. My share \$294,638 over 4 years. Funding starting in 2016.

Effects of cumulative cattle trampling on soil bulk density on an annual forage crop pasture. USDA Southern Regional Sustainable Agriculture Research and Education (SARE). \$10,144.

Graduate students

Kathryn Radicke, MS Effects of cumulative cattle trampling on soil bulk density on an annual forage crop pasture.

Krishna B. Bhandari, PhD. August, 2018. Arthropod and Soil Microbial Communities in Forage-Livestock Systems.

Madhav Dhakal, PhD. May, 2019. Improvement of Perennial Warm-Season Native Grassland with Alfalfa.

Yedan Xiong, PhD. May, 2019. Calibration of ALMANAC Model and APSIM Model for Simulating Growth of WW-B.Dahl Old World Bluestem [*Bothriochla bladhii* (Retz) Blake].

Utah report 2018-2019
Utah State University

1. Impact Nugget:
2. New Facilities and Equipment:
None
3. Unique Project Related Findings:
4. Impact Statements and Accomplishments

Optimizing inputs for forages and field crops in Utah. Earl Creech, project leader.

Data were collected on cover crop contribution, weed growth, wheat yield and wheat yield components in a dryland wheat project in 2018. Wheat yields averaged 1062 to 2165 kg ha⁻¹ in plots treated with 0 and 50 Mg ha⁻¹ compost, respectively. Cover crops appear to have decreased wheat yield.

Employing forage legumes to improve the sustainability of ruminant production. Jennifer MacAdam, project leader.

In a rotational stocking pasture project, we demonstrated that the season-long average fiber (NDF) concentration of cicer milkvetch and birdsfoot trefoil grown in the Mountain West was less than 30% while the non-fibrous carbohydrate (NFC) concentration of these pasture species was nearly 40%. Feedlot diets also contained approximately 30% NDF and 40% NFC. Meadow brome grass in the same study had NDF and NFC concentrations of 50% and 20%, respectively. Carcass weights of feedlot, birdsfoot trefoil- and grass-finished yearling cattle were 370, 343, and 291 kg (816, 763 and 642 lbs.), respectively. The enteric methane emissions on pasture were similar for legume and grass pastures, but legume pasture intake was 40% greater than for grass pastures, resulting in a significantly lower rate of enteric methane emissions per kg intake. Feedlot intake was greater than pasture intake, but enteric methane emissions were similar to feedlot and legume pastures.

Scaling up soil quality assessment and sustainable production at local, landscape and regional levels. Jennifer Reeve, project leader.

In grazing studies, tannin-containing sanfoin significantly reduced nitrate levels in the soil profile. In an organic crop-forage rotation, compost applications increased soil carbon while manure increased soil nitrogen. In an organic fruit study, alleyways planted to birdsfoot trefoil significantly increased soil carbon and nitrogen, and increased nutrient cycling potential in the treerows compared to grass and fallow treatments. The tillage treatment had the lowest measured soil health indicators.

Chemical diversity in rangelands and pasturelands: a sustainable tool to enhance livestock production and ecological health while minimizing environmental impacts. Juan Villalba, project leader.

In a pasture study, alfalfa and birdsfoot trefoil had greater degradability and speed of fermentation than sainfoin, attributable to the greater contents of cell walls and lower concentration of protein in sainfoin. In a cut and carry study, the proportion of alfalfa plus sainfoin or alfalfa plus birdsfoot trefoil (70:30) chosen by lambs given a two-way choice, or the proportion of alfalfa plus birdsfoot trefoil plus sainfoin selected by lambs given a 3-way choice (50:35:15) allowed animals to maintain ruminal degradability and speed of fermentation values comparable to pure alfalfa, and at the same time reduce the risk of bloating while improving the utilization of dietary protein.

In a hay feeding study, tannin-containing hays, as well as other non-traditional tannin-free legumes such as cicer milkvetch have the potential to reduce environmental impacts relative to alfalfa hay by lowering methane emissions and nitrogen excretion in urine. These results are significant for beef production systems as they suggest that non-traditional hays containing bioactive secondary compounds could contribute to reductions in methane production during the cow-calf phase while maintaining or enhancing levels of animal productivity.

5. Published Written Works

Refereed publications

- Clemensen, A., G.E. Rottinghaus, S.T. Lee, F.D. Provenza, and J.J. Villalba. 2018. How planting configuration influences plant secondary metabolites and total N in tall fescue (*Festuca arundinacea* Schreb.), alfalfa (*Medicago sativa* L.) and birdsfoot trefoil (*Lotus corniculatus* L.): Implications for grazing management. *Grass and Forage Science*,73: 94-100.
- Costes-Thire, M., J. Villalba, H. Hoste, and C. Ginane. 2018. Increased intake and preference for tannin-rich sainfoin (*Onobrychis viciifolia*) pellets by both parasitized and non-parasitized lambs after a period of conditioning. *Applied Animal Behaviour Science* 203: 11-18.
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- Gregorini, P., F. D. Provenza, J. Villalba, P. Beukes, and M. Forbes. 2018. Dynamics of forage ingestion, oral processing and digesta outflow from the rumen: a development in a mechanistic model of a grazing ruminant, MINDY. *Journal of Agricultural Science* 156: 980-995.
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Bulletins and Extension Factsheets

Leggett, K., R. Brain, J.W. MacAdam, and J. Villalba. 2018. Rocky Mountain Trefoil Beef. Cooperative Extension sustainability/2018/01pr ed., Utah State University, Logan.

Stewart, E., J.W. MacAdam, and J. Villalba. 2018. Alternative legume species can reduce the environmental impacts of cattle. Cooperative Extension AG/Forage/2018-02pr ed.. Utah State University, Logan.

Stewart, E.K., J. Villalba, and K. Rood. 2018. Environmental and animal benefits when beef cattle consume condensed and hydrolysable tannins. Cooperative Extension AG/Forage/2018-01pr ed. Utah State University, Logan.

Briscoe, J., J.E. Creech, M. Peel, B. Waldron, G. Cardon, and K. Heaton. 2018. Successfully inter-seeding legumes into existing cool-season pastures. Cooperative Extension AG/Crops/2018-01pr, Utah State University, Logan.

Popular Press

MacAdam, J. W. 2018. Legume-finished beef. *Hay and Forage Grower*, April-May, pp. 30-31.

Tracy, B.F., K. Albrecht, J. Flores, M. Hall, A. Islam, G. Jones, W. Lamp, J.W. MacAdam, H. Skinner, and C. Teutsch. 2018. Evaluating grass-legume mixtures across different environments. *Crops and Soils*, 51: 30-34 & 47.

Cherney, J.H., K.A., Albrecht, M.T. Berti, M. Bohle, S.C. Bosworth, K.A. Cassida, W.J. Cox, J. E. Creech, S.C. Fransen, M.H. Hall, D.B. Hannaway, M.A. Islam, K.D. Johnson, J. W. MacAdam, E.C. Meccage, D.H. Putnam, E.B. Rayburn, C.C. Sheaffer, G. Shewmaker, J. Solomon, R.M. Sulc, and J.J. Volenec. 2018. Forage crops need respect. *Hay and Forage Grower* 33: 18-19.

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Whitesides, R.E., and J.E. Creech, 2018. When the alfalfa stand is done. *Progressive Forage* 19: 22-23.

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6. Scientific and Outreach Presentations

Abstracts, symposium and conference presentations

Bolletta, A., J. Villalba, X. Dai, and J.W. MacAdam. 2018. In vitro digestibility and fermentation kinetics of six irrigated forage hays in the US Intermountain West. *Journal of Animal Science*, Suppl. 3, 96: 218-219.

Briscoe, J., M. Peel, and J.E. Creech. 2018. Forage nutritive value in alfalfa, birdsfoot trefoil, cicer milkvetch, orchardgrass, perennial ryegrass, and tall fescue at differing stages of maturity through the growing season. North American Alfalfa Improvement Conference, Logan, UT.

- Briscoe, J., M. Peel, J.E. Creech, B. Waldron, and R.L. Miller. 2018. Inter-seeding forage legumes into existing cool-season grass pastures. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.
- Creech, J.E., M. Deakin, J. Reeve, D.J. Hole, and A. Jacobson. 2018. Long-term compost effects in dryland organic wheat-fallow systems. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.
- Creech, J.E., S. Orloff, and R. Wilson. 2018. Glyphosate injury to glyphosate resistant alfalfa. Western Society of Crop Science Annual Meeting, Laramie, WY.
- Lagrange, S., R. Guevara Ballesteros, K. Beauchemin, J.W. MacAdam, and J. Villalba. 2018. Methane emissions by cattle grazing tannin-containing legumes. *Journal of Animal Science Suppl.* 3, 96: 223-224.
- MacAdam, J. W. 2018. Forage Legumes for Meat and Milk Production. North America Alfalfa Improvement Conference, Logan, UT.
- Rose, M., B. Waldron, J.E. Creech, S. Isom, and M. Peel. 2018. Grass-birdsfoot trefoil mixtures to improve pasture-based dairy performance. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.
- Rose, M., B. Waldron, J.E. Creech, S. Isom, M. Peel. 2018. Grass-birdsfoot trefoil mixtures to improve pasture-based dairy performance. North American Alfalfa Improvement Conference, Logan, UT.
- Slebochnik, K. J.M. Norton, J.W. MacAdam, and J. Reeve. 2018. Effects of tannins on nitrogen cycling in pasture soils. Spring Runoff Conference, Utah State University, Logan, Utah.
- Villalba, J., K. Beauchemin, K., and J.W. MacAdam. 2018. Nutrients and plant secondary compounds in pasturelands and their ecological services. *Journal of Animal Science*, Suppl. 3, 96: 211.
- Villalba, J. 2018. Self-selection of plant bioactive compounds by sheep in response to challenge infection with *Haemonchus contortus*. American Society of Animal Science (ASAS) - Canadian Society of Animal Science (CSAS), July 8, 2018 - July 12, 2018, Vancouver, Canada.
- Wan, J., J.E. Creech, Y. Wang, X. Zhang, Z. Yu. 2018. Effects of wilting and additives on the fermentation quality, chemical composition and in vitro of sudangrass silage. Western Society of Crop Science Annual Meeting, Laramie, WY.
- Zhang, Y., and J.W. MacAdam. 2018. In vitro rumen fermentation of six pasture species and their isolated fiber. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.

7. Collaborative Grants

- Isom, S.C., R.H. Miller, A.L. Young, M.I. Peel, B.L. Waldron, J.E. Creech, K.E. Rood, D.I. Feuz, D.E. Heleba, and K.A. Thornton-Kurth. 01/09/17-31/08/20. Economic and environmental sustainability of heifer development strategies in pasture-based organic dairy systems. Grant 2017-51300-26866, \$999,404. USDA NIFA Organic Agriculture Research and Extension Initiative program.
- MacAdam, J.W. 07/01/18-06/30/19. Cattle Methane Emissions, Nitrogen Use and Fatty Acid Processing of Legumes. \$32,886.42. State of Utah Pasture and Forage Initiative.
- MacAdam, J.S., R.E. Ward, and K. Hintze. 05/01/18-04/30/20. Understanding the increased omega-3 fatty acid concentration in legume-fed beef. \$20,000. USU Office of Research and Graduate Studies, Research Catalyst Grant.

Reeve, J.R., A.J., Caplan, M.-K. Kim, C.E. Dyreson, J.W. MacAdam, and B. Chamberlain. 07/01/18-06/30/20. Scenario analysis of ecosystem services of agricultural land along the Wasatch Front, Utah. \$60,000. UAES Seed Grant,

Stark, J.O., J.M. Norton, and J.W. MacAdam. 02/15/16-02/14/20. Microbial carbon-use efficiency in agroecosystems: The effect of drought and N availability on soil microbial production and respiration. Grant# 2016-67004-24920. \$714,080. USDA NIFA AFRI Climate and Microbial Processes in Agroecosystems program.

Villalba, J.J., J.W. MacAdam, Caplan, A.J., J.R. Reeve, M.-K. Kim, R. McCann, and J.M. Norton. 06/01/16-05/031/20. Co-P.I. Tannin-containing legumes in pasturelands and their ecological services. Grant #2016-67019-25086. \$499,884. USDA NIFA AFRI Agroecosystem Management program.

Villalba, J.J., J.W. MacAdam, M.-K. Kim, and E. Burritt. 02/15/16-02/14/19. Legume-finished beef: Achieving current production with greater environmental, economic and social sustainability. Grant #2016-69004-24855. \$150,000. USDA NIFA AFRI Food Security program.

8. Graduate students

Allen, Britney. Masters. Spring 2020. Fatty acid composition of forages and their effect on the fatty acid composition in beef cattle.

Bolletta, Andrea Ivana. Spring 2020. Enhancing the sustainability of pasture-based beef production.

Wisconsin Report 2018-2019
University of Wisconsin - Madison

1. Impact Nugget:

Forages research at University of Wisconsin – Madison focuses on resilience of alfalfa and other forages to climate change, agronomic management of emerging dual-use perennial grain and forage crops like Kernza intermediate wheatgrass, and ecological intensification of livestock systems.

2. New Facilities and Equipment:

Seed cleaner for intermediate wheatgrass and forage/cover crops seeds purchased.

3. Unique Project Related Findings:

Accomplishments summaries:

We have developed a research program in sustainability of forage and grazing systems in the Midwestern United States and the world. We do research in Agroecology to understand, predict, and develop sustainable agricultural systems with emphasis of exploiting the multiple benefits of perennials and crop diversity. My research program has generated ~\$1 Million in extramural funding and \$175K in intramural funds. My research program is oriented in three interacting directions to promote agricultural sustainability. First, I lead regional and international teams to optimize agronomic management of new perennial dual-purpose crops for forage and grain, with an emphasis on crop mixtures (polycultures). Second, I measure and study the scientific basis for the resilience of forages and farming systems to climate variability and change. Third, my program expands internationally, assessing the agroecological intensification of grazing systems in the world, especially in Latin America. My main research accomplishments are indicated below:

1. Agronomic management of perennial dual-purpose crops in polycultures

Perennial crops in polycultures can fundamentally transform agriculture systems, and reconcile food production with environmental sustainability. Compared to current annual crops, perennials have extensive root systems which reduce soil erosion, nutrient runoff, water pollution, and pesticide requirements while increase farmer income due to decreased inputs and costs. Intermediate wheatgrass (*Thinopyrum intermedium*) is the first perennial grain crop in the world, currently marketed as “Kernza”. My research is developing this perennial crop into a dual-use, grain and forage system, which will increase profitability, reduce adoption risks for farmers, and facilitate a landscape-scale transition to perennial agriculture in the US Upper Midwest. My program focuses on evaluating forage yield and nutritive value of dual-use Kernza systems and identifying agronomic management practices that optimize grain and forage yield, while documenting agroecological benefits of perennial polycultures. My team is evaluating a wide range of agronomic management treatments including timing and frequency of forage harvest, direct grazing, species and seeding time of companion legumes, nitrogen fertilization, weed management, and post-grain harvest practices on Kernza grain yield and forage quality over time. We’ve documented high forage yield and nutritive value of these systems (Favre et al. in review), great weed suppression of annual weeds, low Nitrogen requirements, and good compatibility with legumes (Zimbric et al. in review.), and determined non-structural carbohydrates in roots and rhizomes (Dong et al. in prep.). We have identified farmers perspectives and research needs that inform this program (Lanker et al. 2019). We are also exploring other perennial grains like Silphium (Van Tassel et al. 2017). International expansion of perennial grains is also my interest, and I have collaborations with Uruguay, Argentina, Chile, China, Japan, Ukraine, Sweden, Italy and Switzerland to study the potential for Kernza growth and production in these regions.

Understanding vernalization and photoperiod requirements is a critical point to this goal, and we have evaluated optimal conditions and variability in germplasm to these factors (Ivancic et al. in prep., Locatelli et al. in prep.). This research has been funded by NCR-SARE grant (PI), The Land Institute gift funds (PI), FFAR fellowship (PI), NAFA (co-PI), and UW-Madison (startup funds, WARF-VCRGE, Hatch-pending). Three of my UW-Madison students are working on this direction, as well as one student from China and one from Uruguay.

2. Resilience and stability to climate variability and change

Climate change is a major challenge for agriculture and food security. Agronomic research has historically paid little attention to maximizing the ability to recover after a major climate crisis event (“resilience”) or minimizing long term variability of yields (“stability”). The main goal of my program is to study the resilience and stability of forage systems at multiple levels (cultivars, species, mixtures, cropping systems) in Wisconsin and the US, in order to identify forage species, mixtures, and crop rotations that optimize these long-term features. I have developed a novel methodology (Picasso et al. 2019) to analyze historical data and calculate quantitative measures for resilience and stability; identify more resilient cultivars (Picasso et al. 2019), cropping systems (WICST, Sanford et al. in prep.), and farms (Modernel et al. 2019) and then evaluate those in experimental field conditions and model behavior in future scenarios (NIFA-AFRP grant). I seek to understand which features (e.g., plant anatomical and physiological traits, species diversity, management) are linked to resilience and stability. This research addresses fundamental questions of ecology and agroecology about the role of diversity on the functioning of ecosystems (Picasso, 2018). This research also has applied implications, providing farmers and agronomists with tools to choose and design more resilient and stable systems. This research is funded by HATCH grant (PI) and two federally funded USDA NIFA-AFRP grants (PI and Co-PI). I have one MSc student at UW-Madison and one MSc student in Uruguay working on this. I am recruiting a postdoc.

3. Agroecological intensification of livestock systems internationally

Livestock systems are key to global protein food supply, but they have several environmental impacts. Agroecological intensification of livestock systems is based on optimizing grazing management, minimizing inputs, and maximizing ecological processes. I explore case studies from abroad (Modernel et al. 2018) to gain insight on how to improve their sustainability, using environmental impacts modeling and life cycle assessment. Local information on these systems is crucial, and can only be gathered from local sources, so I rely on strong international collaborations and interdisciplinary teams (Cruz et al. 2017, Pischke et al. 2017). The impact of the application of these studies is high, providing government institutions information for the design of policies (Darre et al. 2018). This research direction is funded by international student’s fellowships, international collaborations, and previous grants. Three of my students from Uruguay (Llanos, Darre, Bussoni), one in the Netherlands (Modernel), and visiting scholar from Peru (Pizarro) are publishing in this direction.

4. Impact Statement

1. Perennial grain and forage crops can contribute significantly to the environmental health, providing millions of dollars in savings on soil conservation, water cleaning, and fertilizer applications. Also this emerging industry can contribute significantly to development of new enterprises for rural communities, increasing farm income by reducing costs and increasing prices of highly valuable products.

2. Increased resilience of forages to climate change can provide millions of dollars in savings on forage production during years of climatic crises like drought or extreme cold winters.

3. Ecological intensification of livestock systems research contributes to policy makers around the world to design policies that conserve natural resources while increasing profitability of livestock farms.

5. Published written work

Peer-reviewed publications

- Andrzejewska J., F.E. Contreras-Govea, P. Berzaghi, and K.A. Albrecht. 2018. Forage accumulation and nutritive value of Italian ryegrass--Kura clover mixture in central Europe. *Crop Sci.* 58:443-449
- Andrzejewska, J., F.E. Contreras-Govea, A. Pastuszka, K. Kotwica, and K.A. Albrecht. 2019. Performance of oat (*Avena sativa* L.) sown in late summer for autumn forage production in Central Europe. *Grass Forage Sci.* 74:97-103.
- Arnold, A.M., K.A. Albrecht, D.J. Barker, and R.M. Sulc. 2019. Predictive equations for alfalfa quality (PEAQ) can be used with reduced-lignin alfalfa. *Crop Forage Turfgrass Manage.* DOI: 10.2134/cftm2019.01.0004
- Arnold, A.M., K.A. Cassida, K.A. Albrecht, M.H. Hall, D.H. Min, X. Xu, S. Orloff, D.J. Undersander, E. van Santen, and R.M. Sulc. 2019. Multistate evaluation of reduced-lignin alfalfa harvested at different intervals. *Crop Sci.* 59:1799-1807.
- Boe, A., K.A. Albrecht, P.J. Johnson, and J. Wu. 2019. Biomass production of cup plant (*Silphium perfoliatum* L.) in response to variation in plant population density in the North Central USA. *Amer. J. Plant Sci.* 10:904-910.
- Boe, A., K.A. Albrecht, P.J. Johnson, and J. Wu. 2019. Biomass production of monocultures and mixtures of cup plant and native grasses on prime and marginal cropland. *Amer. J. Plant Sci.* 10:911-924.
- Bresciano, D., A. Del Pino, A. Borges, M. Tejera, P. Speranza, L. Astigarraga, V. Picasso. 2018. Perennial C4 grasses increase root biomass and carbon in sown temperate pastures. *New Zealand Journal of Agricultural Research*, DOI: 10.1080/00288233.2018.1504089
- Darre, E., M. Cadenazzi, S. R. Mazzilli, J. F. Rosas, V. Picasso. 2018. Environmental impacts on water resources from summer crops in rainfed and irrigated systems. *Journal of Environmental Management* 232:514-522.
- Favre, J.R., K.A. Albrecht, L. Gutierrez, V.D. Picasso. 2019. Harvesting oat forage at late heading increases milk production per unit of area. *Crop Forage Turfgrass Manage.* doi:10.2134/cftm2018.06.0046
- Favre, J.R., T. Munoz Castiblanco, D.K. Combs, M.A. Wattiaux, and V.D. Picasso. 2019. Forage nutritive value and fiber digestibility of Kernza intermediate wheatgrass in monoculture and in mixture with red clover during the first production year. *Animal Feed Sci. Technol.* (*under review*).
- Kazula, M., J. Andrzejewska, S.P. Conley, and K.A. Albrecht. 2019. Intercropping winter cereals in Kura clover for spring forage production. *Can. J. Plant Sci.* (in press)
- Lanker, M., M. Bell, and V. Picasso. 2019. Farmer perspectives and experiences introducing the novel perennial grain Kernza Intermediate wheatgrass in the US Midwest. *Renew. Agric Food Sys.* 1900031: 1-10. <https://doi.org/10.1017/S1742170519000310>
- Llanos, E., L. Astigarraga, V. Picasso. 2018. Energy and economic efficiency in grazing dairy systems under alternative intensification strategies. *Eur. J. Agron.* 92: 133-140

- Modernel, P., S. Dogliotti, S. Alvarez, M. Corbeels, V. Picasso, P. Tiftonell, W.A. Rossing. 2018. Identification of beef production farms in the Pampas and Campos area that stand out in economic and environmental performance. *Ecological Indicators* 89:755-770
- Modernel, P., V. Picasso, M. Do Carmo, W.A. H. Rossing, M. Corbeels, P. Soca, S. Dogliotti, P. Tiftonell. 2019. Grazing management for more resilient mixed livestock farming systems on native grasslands of southern South America. *Grass Forage Sci.* DOI: 10.1111/gfs.12445
- Nieman, C.C., K.A. Albrecht, and D.M. Schaefer. 2019. Temporal composition of alfalfa-grass pastures and productivity response of Holstein steers. *Agron. J.* 111:686-693.
- Picasso, V., M. Casler, D. Undersander. 2019. Resilience, stability, and productivity of alfalfa (*Medicago sativa* L.) cultivars in rainfed regions of North America. *Crop Sci.* 59:1–11. doi: 10.2135/cropsci2018.06.0372
- Picasso, V. 2018. The “biodiversity – ecosystem function debate”: an interdisciplinary dialogue between Ecology, Agriculture and Agroecology. *Agroecol. Sust. Food Sys.*42(3):264-273
Proceedings and Abstracts
- Picasso, V.; M.C. Casler and D. Undersander. 2019. Resilience and stability of alfalfa cultivars in North America. International Forage and Turfgrass Breeding Conference, Orlando, FL, USA.
- Picasso, V., and A. Locatelli. 2019. Variability in vernalization requirements of Kernza intermediate wheatgrass populations. International Forage and Turfgrass Breeding Conference, Orlando, FL, USA.
- Zimbric, J., V. Picasso, and D. Stoltenberg. 2018. Plant growth regulator effects on intermediate wheatgrass-weed communities. North Central Weed Sci. Soc. Meeting. Milwaukee, WI.
- Favre, J. and V. Picasso. 2018. Forage Yield and Nutritive Value of Perennial Grain Kernza Grown in Monoculture and Intercropped with Red Clover. ASA-CSSA annual meetings, Baltimore, MD, USA.
- Favre, J., J. Jungers, N. Tautges, C. Sheaffer, and V. Picasso. 2018. Effects of spring and fall grazing on grain Yield, Forage Yield and Forage Nutritive Value of Perennial Grain Kernza Grown in Monoculture and Intercropped with Red Clover. ASA-CSSA annual meetings, Baltimore, MD, USA.
- Zimbric, J.; D.E. Stoltenberg; and V. Picasso. 2018. Intermediate wheatgrass (*Thinopyrum intermedium*): Legume-Intercrop Mixtures Suppress Weed Productivity during the First and Second Production Years. ASA-CSSA annual meetings, Baltimore, MD.
- Zimbric, J.; D.E. Stoltenberg; and V. Picasso. 2018. Perennial Grain and Forage Intermediate Wheatgrass (*Thinopyrum intermedium*) Cropping Systems Effectively Suppress Weeds during the First Three Production Years. ASA-CSSA annual meetings, Baltimore, MD.
- Ivancic, K.; W. Trac and V. Picasso. 2018. Economic Optimum N in Kernza Cropping Systems Using Organic and Inorganic N Sources. ASA-CSSA annual meetings, Baltimore, MD.
- Ivancic, K.; W. Tracy; V. Picasso. 2018. Kernza-Red Clover Intercropping: Nitrogen and Root Mass Dynamics. ASA-CSSA annual meetings, Baltimore, MD, USA.
- Dong, C.; Sakiroglu M.; M.B. Hall; V. Picasso. 2018. Forage Harvest and Nitrogen Affect Non-Structural Carbohydrates in Kernza Intermediate Wheatgrass (*Thinopyrum intermedium*) Root Systems. International Congress on Agriculture and Animal Sciences, Alanya, Turkey.

- Favre, J. and V. Picasso. 2018. Forage yield and nutritive value of perennial grain Kernza grown in monoculture and intercropped with red clover. North American Alfalfa Improvement Conference, Logan, UT, USA.
- Picasso, V.; M.C. Casler and D. Undersander. 2018. Resilience, stability and productivity of alfalfa in North America. North American Alfalfa Improvement Conference, Logan, UT, USA.
- Sanford, G.R., Jackson, R.J., Picasso, V. 2018. Resilience and stability of productivity in integrated cropping systems of the Wisconsin Integrated Cropping Systems trial. In: 2018 The future of long-term experiments in agricultural science. Rothamsted Research, Harpenden, UK. p. 48.

6. Scientific and Outreach Presentations

Other publications (magazines, extension/online/bulletins)

7. Collaborative grants

- Picasso, V., C. Sheaffer, et al. USDA – NCR-SARE, \$200,000. 2016 – 2019. Grazing management of "Kernza" Intermediate wheatgrass as a dual-purpose crop
- Bell, M., V. Picasso, et al. USDA-ARS. \$ 7,000. 2017 – 2020. Cover Crops, Water Quality, and Soil Health Research and Outreach (C-CROP)
- Picasso, V. The Land Institute. \$85,000. 2017 – 2020. Ecosystem Servicing of Perennial Grains Kernza and Silphium
- Picasso, V. The Land Institute. \$30,000. 2016 – 2019. Perennial grain polycultures in Wisconsin
- Jungers, J., V. Picasso, et al. USDA – NCR-SARE. \$40,000. 2019-2021. Intercropping the perennial grain Kernza with legumes for sustained economics and environmental benefits
- Picasso, V. et al. USDA-NIFA-AFRP \$300,000. 2018-2021. Resilience of Alfalfa Cultivars to Variable Environments.
- Schlautman, B., V. Picasso, et al. NAFA \$40,000. 2018-2019. Identifying optimal alfalfa germplasm for intercropping with perennial grasses (...)
- Crews, T., V. Picasso, et al. Patagonia Provisions. \$75,000. 2018-2023. Greenhouse gas fluxes from perennial grain polyculture systems using Eddy-covariance
- Sheaffer, C., V. Picasso, et al. USDA-NIFA- AFRP \$65,000. 2019-2021. Evaluating alfalfa winter survival
- Picasso, V. UW-VCRG-Fall Competition. \$74,725. 2018 -2019. Developing perennial grain polyculture Kernza-legume systems in Wisconsin
- Picasso, V. USDA-Hatch \$100,000. 2017–2021. Resilience, stability, and productivity: from cultivars to cropping systems
- Picasso, V. USDA-Hatch. \$140,000 2019–2022. Designing perennial grain and forage cropping systems for Wisconsin

8. Graduate students

- Marisa Lanker, 2017-18, MSc Agroecology, Kernza farmers perceptions
- Jeremie Favre, 2017-19, MSc Agronomy, Grazing Kernza forage
- Joe Zimbrick, 2017-19, MSc Agronomy, Kernza weed ecology
- Sarah Bullock, 2018-21, MSc Agronomy, Resilience in oats
- Stefania Cartoni, 2018-21, MSc Agroecology, Kernza management mixtures with legumes
- Olugakorede Olugbenle, 2019-22, MSc Agroecology, Kernza agronomic practices

Wyoming report 2018-2019

University of Wyoming

1. Impact Nugget:

The University of Wyoming's research has made selection for well-adapted high performing accessions/lines which resulted in development of cultivars that are suitable for Wyoming and neighboring states. The studies at the university contributed to the improvement of productivity of local and regional producers and would provide economic benefits in the long-run.

2. New Facilities and Equipment:

Modified and updated a planter (Tye Drill) for planting forage species more efficiently for different experiments.

3. Unique Project Related Findings:

The weather in Wyoming in 2018 was comparatively dry compared to 2016 and 2017. This allowed to better compare growth and yield performance of accessions/lines of consecutive different years.

4. Accomplishments:

In Wyoming, forages are very important and the mainstay of livestock production. Alfalfa is an important forage crop in the US and produces high quality forage. Frequent harvest and baling of alfalfa lead to high removal of nutrients, particularly potassium (K), from the soil. This results in soil K depletion with a detrimental effect on productivity of alfalfa in subsequent growing seasons. Annual application of K is important to sustain K levels in soil to increase alfalfa production in long term. Yield response of alfalfa to K when it is added to soils with high-test K levels is not clear. The objective of the study is to determine the effect of K fertility along with harvest time management on the productivity of newly released alfalfa cultivars. Data being collected include plant growth, dry matter yield, forage quality, and K uptake. It is anticipated that the results obtained from this study will help recommend the best fertility management guide for alfalfa producers in Wyoming and neighboring states.

New and suitable plant materials demand is a long-term issue and is increasing continuously especially in the Intermountain West region. The objective of this long-term study is to evaluate different advanced lines of C3 grasses with the inclusion of some local checks in relation to their growth, yield, and quality response to irrigation, drought, and planting time. Species used in this study include tall fescue (seven lines), tall wheatgrass (three lines), western wheatgrass (five lines), and wildrye (two lines). Data collected on different growth parameters, persistence, and forage quality from 2009 - 2018 seems to be different among species and lines. Long-term data collection will help select and develop superior and well-adapted cultivars.

5. Impact Statements:

Research at the University of Wyoming has made selection for well-adapted high performing accessions/lines which resulted in development of cultivars that are suitable for Wyoming

and neighboring states. This contributed to the improvement of productivity of local and regional producers and in the long-run, would provide economic benefits.

Studies on determining cost effectiveness of establishing alfalfa, sole grass (fertilized with N), sole legumes, and grass-legume mixtures and how efficient these practices are utilizing irrigation water and fertilizer, in particular K, have positive impacts. Results will help recommend the best establishment and management practices that will be profitable to Wyoming producers by reducing production cost significantly.

6. Published Written Works:

Peer-Reviewed Journal Articles

- Islam, M.A. and Adjesiwor, A.T. 2019. Nitrogen fertilization in tall fescue: Productivity, agronomic efficiency and relative profitability. *Grassland Science*. (In press).
- Homer, A., Islam, M.A., Krall, J.M., Nachtman, J.J., and Groose, R.W. 2019. Registration of 'WyoWinter' Feed Pea for the US Central Great Plains. *Journal of Plant Registrations*. 13:128-133. doi:10.3198/jpr2018.07.0047crc.
- Aryal, P. and Islam, M.A. 2018. Effect of forage kochia on seedling growth of cheatgrass (*Bromus tectorum*) and perennial grasses. *Invasive Plant Science and Management*. 11:201–207. doi: 10.1017/inp.2018.27.
- Aryal, P. and Islam, M.A. 2018. Establishment of forage kochia in seeding mixtures with perennial grasses. *Grassland Science*. 00:1–8. doi.org/10.1111/grs.12228.
- Islam, M.A. and Ashilenje, D. 2018. Diversified forage cropping systems and their implications on resilience and productivity. *Sustainability*. 10, 3920; doi:10.3390/su10113920.
- Nilahyane, A., Islam, M.A., Mesbah, A.O., and Garcia y Garcia, A. 2018. Effect of irrigation and nitrogen fertilization strategies on silage corn grown in semi-arid conditions. *Agronomy*. 8, 208; doi:10.3390/agronomy8100208.
- Dhakal, D. and Islam, M.A. 2018. Grass-legume mixtures for improved soil health in cultivated agroecosystem. *Sustainability*. 10, 2718; doi:10.3390/su10082718.
- Nilahyane, A., Islam, M.A., Mesbah, A.O., and Garcia y Garcia, A. 2018. Evaluation of silage corn yield gap: An approach for sustainable production in the semi-arid region of USA. *Sustainability*. 10, 2523; doi:10.3390/su10072523.
- Tracy, B.F., Foster, J.L., Butler, T.J., Islam, M.A., Toledo, D., and Vendramini, J.M.B. 2018. Resilience in Forage and Grazinglands. *Crop Science*. 58:31–42. doi: 10.2135/cropsci2017.05.0317.

Book Chapter (Refereed)

- Islam, M.A. and Adjesiwor, A. T. 2019. Moisture Stress and its Effects on Forage Production Systems. In: Handbook of Plant and Crop Stress, 4th Edition (M. Pessarakli, Ed.). CRC Press, Taylor & Francis Publishing Company, Florida. (In press).
- Islam, M.A. and Nilahyane, A. 2019. Water Stress Effects on Growth and Physiology of Corn. In: Handbook of Plant and Crop Stress, 4th Edition (M. Pessarakli, Ed.). CRC Press, Taylor & Francis Publishing Company, Florida. (In press).

Abstracts

- Islam, M.A. and Baidoo, M. 2019. Soil Potassium Levels and Its Effect on Alfalfa Productivity. Proceedings of the SSSA International Soils Meeting January 6-9, 2019. San Diego, CA

(American Society of Agronomy, Crop Science Society of America, Soil Science Society of America).

- Baidoo, M. and Islam, M.A. 2018. Response of Alfalfa Cultivars to Potassium and Harvest Time. Proceedings of the ASA-CSSA International Annual Meetings November 4-7, 2018. Baltimore, MD (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America).
- Baidoo, M. and Islam, M.A. 2018. Effect of Potassium and Harvest Time on Potassium Uptake and Nutritive Value of Alfalfa. Proceedings of the ASA-CSSA International Annual Meetings November 4-7, 2018. Baltimore, MD (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America).
- Savage, A.C., Sivanpillai, R., and Islam, M.A. 2018. Monitoring crop growth variations in a Wyoming field using growing season satellite data. Proceedings of the 2018 GIS in the Rockies Conference September 19-20, 2018. Denver, CO (GIS in the Rockies).
- Islam, M.A. 2018. Response of Alfalfa to Soil Potassium, Cultivars, and Harvesting Intervals. Proceedings of the International Congress and Expo on Agriculture and Horticulture August 13-14, 2018. Amsterdam, Netherlands (Scientific Federations, UK).
- Baidoo, M. and Islam, M.A. 2018. Effect of Potassium and Harvest Time on Forage Accumulation and Potassium Uptake of Alfalfa. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).
- Baidoo, M. and Islam, M.A. 2018. Potassium and Harvest Time Affect Production and Nutritive Value of Alfalfa. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).
- Ashilenje, D.S. and Islam, M.A. 2018. Plant community structure and nitrogen dynamics underlie sustained productivity of grass-legume forage mixtures in Wyoming. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).
- Ashilenje, D.S. and Islam, M.A. 2018. Benefits of grass-legume mixture extend to nitrogen gains and alleviation of greenhouse gas emissions in Wyoming. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).
- Khatiwadal, B., Acharya, S.N., Larney, F., Lupwayi, N.Z., Smith, E., and Islam, M.A. 2018. Ability of sainfoin and cicer milkvetch populations to rejuvenate existing pastures in western Canada. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).
- Islam, M.A. 2018. The silent decline in soil potassium levels and its effect on alfalfa productivity in the Central and Western U.S. Proceedings of the North American Alfalfa Improvement Conference Annual Meetings June 4-6, 2018. Logan, UT (NAAIC, Trifolium, & Grass Breeders).

Extension publications

- Dhakal, D. and Islam, M.A. 2018. Grass-legume mixtures can maximize farm profits in Wyoming. University of Wyoming Extension Bulletin B-1329, Ed. S.L. Miller, pp.1-4, September 2018. University of Wyoming, Laramie.

- Dhakal, D. and Islam, M.A. 2018. Grass-legume mixtures can improve soil health. University of Wyoming Extension Bulletin B-1328, Ed. S.L. Miller, pp.1-4, August 2018. University of Wyoming, Laramie.
- Ashilenje, D. and Islam, M.A. 2018. Meadow bromegrass-legume mixtures for diversified and profitable hay production in Wyoming. University of Wyoming Extension Bulletin B-1327, Ed. S.L. Miller, pp.1-7, July 2018. University of Wyoming, Laramie.
- Nilahyane, A. and Islam, M.A. 2018. Different irrigation systems and nitrogen rates improve yield and water use efficiency of corn silage. University of Wyoming Extension Bulletin B-1326, Ed. S.L. Miller, pp.1-6, June 2018. University of Wyoming, Laramie.
- Islam, M.A. and Ashilenje, D. 2018. Have a plan prior to drought for pasture management. *In: Navigating Drought in Wyoming*. University of Wyoming Extension Bulletin B-1325, Ed. B. Sebade and S.L. Miller, pp.19-21, June 2018. University of Wyoming, Laramie.
- Adjesiwor, A. and Islam, M.A. 2018. Birdsfoot Trefoil: Establishment and Management as Monocultures and Mixtures in Wyoming. University of Wyoming Extension Bulletin B-1321, Ed. S.L. Miller, pp.1-7, May 2018. University of Wyoming, Laramie.
- Aryal, P. and Islam, M.A. 2018. Forage Kochia Establishment: Effects of Planting Time and Grass Mixtures. University of Wyoming Extension Bulletin B-1318, Ed. S.L. Miller, pp.1-4, April 2018. University of Wyoming, Laramie.
- Ashilenje, D. and Islam, M.A. 2018. Species Composition and Nitrogen Fixation Affect Forage Yield and Nutritive Value of Irrigated Meadow Brome-Legume Mixtures. 2018 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 154-155.
- Horn, B., Islam, M.A., Smith, D., Jeliaskov, V., and Garcia y Garcia, A. 2018. Perennial Cool-Season Grasses Under Irrigation for Hay Production and Fall Grazing. 2018 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 152-153.
- Baidoo, M. and Islam, M.A. 2018. Effect of Potassium on Yield of Newly Released Alfalfa Cultivars. 2018 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 100-101.
- Islam, M.A., Ashilenje, D., and Baidoo, M. 2018. Evaluation of forage sorghum under irrigated and dryland conditions in Wyoming. 2018 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, p. 90.
- Islam, M.A., Ashilenje, D., and Baidoo, M. 2018. Evaluating chickpea cultivars for forage and grain production in Wyoming. 2018 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, p. 89.
- Stahl, P., Eberle, C., Islam, M.A., Norton, J., and Coupal, R. 2018. Use of pyrolyzed coal and biochar as a soil amendment. 2018 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, p. 89.
- Islam, M.A. 2018. Farm profitability from grass-legume mixtures. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, December 29, 2018.
- Islam, M.A. 2018. Soil health benefits from grass-legume mixtures. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, October 27, 2018.
- Islam, M.A. 2018. Legume inoculation – an important factor for sustainable forage production- Part III. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, August 4, 2018.

- Islam, M.A. 2018. Legume inoculation – an important factor for sustainable forage production- Part II. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, May 26, 2018.
- Islam, M.A. 2018. Legume inoculation – an important factor for sustainable forage production- Part I. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, March 3, 2018.
- Cherney, J.H., Islam, M.A., Albrecht, K.A. et al. 2018. Forage Crops Need Respect. *Hay & Forage Grower*, August/September 2018, pp. 18-19. Available at <http://www.hayandforage.com>.

7. Scientific and Outreach Oral Presentations

- Islam, M.A. 2018. Integrated Research and Extension Work on Forage Crops. University of Wyoming Extension Specialist Meeting Seminar, December 10, 2018. University of Wyoming, Laramie, WY. Attendance: 25.
- Islam, M.A. 2018. Potassium and Harvest Management in Alfalfa. The 6th Annual Wyoming Forage Field Day, June 12, 2018. James C. Hageman Sustainable Agriculture Research and Extension Center, Lingle, WY. Attendance: 100.
- Islam, M.A., Ashilenje, D., Baidoo, M., and Shilpakar, C. 2018. Forage Research Updates in Lingle. The 6th Annual Wyoming Forage Field Day, June 12, 2018. James C. Hageman Sustainable Agriculture Research and Extension Center, Lingle, WY. Attendance: 50.
- Islam, M.A. 2018. Organic Forage Production: Options and Considerations. The 5th Annual High Plains Organic Farming Conference, February 28, 2018. Laramie County Community College, Cheyenne, WY. Attendance: 35.
- Islam, MA. 2018. Agronomy in Alfalfa. Alfalfa U – Loveland CO High Plains Journal, February 6, 2018. Loveland, CO. (*breakout presentation 2*) Attendance: 28.
- Islam, MA. 2018. Agronomy in Alfalfa. Alfalfa U – Loveland CO High Plains Journal, February 6, 2018. Loveland, CO. (*breakout presentation 1*) Attendance: 40.
- Islam, M.A. 2018. Diversified Forage Cropping Systems: Impacts on Resiliency, Productivity, and Profitability. Department of Plant Sciences Seminar December 7, 2018. University of Wyoming, Laramie, WY. Attendance: 23.
- Baidoo, M. and Islam, M.A. 2018. Response of Alfalfa Cultivars to Potassium Application and Harvest Time. The ASA-CSSA International Annual Meetings November 7, 2018. Baltimore, MD. Attendance: 37.
- Islam, M.A. 2018. Response of Alfalfa to Soil Potassium, Cultivars, and Harvesting Intervals. The International Congress and Exo on Agriculture and Horticulture August 14, 2018. Amsterdam, Netherlands. Attendance: 55.
- Islam, M.A. 2018. Wyoming NCCC-31 Report-Ecophysiological Aspects of Forage Management. University of Arkansas, June 21 2017. Fayetteville, AR. Attendance: 20.
- Baidoo, M. and Islam, M.A. 2018. Effect of Potassium and Harvest Time on Forage Accumulation and Potassium Uptake of Alfalfa. The Western Society of Crop Science Annual Meetings June 20, 2018. Laramie, WY. Attendance: 35.
- Ashilenje, D.S. and Islam, M.A. 2018. Plant community structure and nitrogen dynamics underlie sustained productivity of grass-legume forage mixtures in Wyoming. The Western Society of Crop Science Annual Meetings June 20, 2018. Laramie, WY. Attendance: 35.
- Khatiwadal, B., Acharya, S.N., Larney, F., Lupwayi, N.Z., Smith, E., and Islam, M.A. 2018. Ability of sainfoin and cicer milkvetch populations to rejuvenate existing pastures in

western Canada. The Western Society of Crop Science Annual Meetings June 20, 2018. Laramie, WY. Attendance: 35

Islam, M.A. 2018. The silent decline in soil potassium levels and its effect on alfalfa productivity in the Central and Western U.S. The North American Alfalfa Improvement Conference Annual Meetings June 6, 2018. Logan, UT. Attendance: 95.

8. Fund leveraging, specifically, collaborative grants between stations and members

USDA NIFA Crop Protection and Pest Management (CPPM). 2019-2022. Jabbour, R., Rand, T.A., Peairs, F., Islam, M.A., Ritten, J., and Lee, B. Integration of Early Harvest with Biological Control for Sustainable Alfalfa Production. \$324,998.

Specialty Crop Block Grant Program – Farm Bill (SCBGP-FB), USDA Wyoming Department of Agriculture. 2019-2021. Islam, M.A. Evaluation of Yacon in Rotation with Fenugreek in Wyoming Environments. \$50,000.

Energy GA Fellowships, UW. 2018-2020. Islam, M.A. Reclamation of disturbed areas used by gas industries in Wyoming by using some promising grass and legume genotypes. \$55,008.

Y Cross Ranch Tuition and Fee Award, COANR, UW. 2018-2019. Islam, M.A. Developing a potassium fertility management program on alfalfa. \$9,000.

Edward H. and Susan King Lloyd Graduate Research Award, UW. 2018-2019. Islam, M.A. and Baidoo, M. Potassium and harvest management in alfalfa. \$3,000.

UW School of Energy Resources. 2018-2019.

Stahl, P.D., Eberle, C.A., Norton, J.B., Islam, M.A., and Coupal, R.H. Use of Coal Residues as a Soil Amendment. \$83,000.

9. Other relevant accomplishments and activities

Forage production, management, quality, and economic returns have been presented at Wyoming Forage Field Day, Agriculture Experimentation Field Days, and local and regional workshops/meetings.