**STATE REPORTS 2022**

**NCCC31 – Ecophysiological Aspects of Forage Management**

**Arkansas**

1. Impact Nugget:

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

The group from the University of Arkansas is engaged in applied research and extension activities pertaining to the use of native and introduced annuals, perennials, warm and cool season forages. Our current activities, based on external funding, focus on determining nitrogen fluxes at the soil-plant-animal interface, soil water retention under retention, forage establishment and growth in wooded areas, and prairie reconstruction for roadside management.

2. New Facilities and Equipment:

Volumetric Water Content (VWC) sensors, drone (hyper and multi-spectral camera), an electrical conductivity (EC) meter, GPS cattle collars, and a C:N analyzer were procured to attain research-quality accuracy in measurement of soil-water in integrated forage-animal grazing systems.

Over the past 12 months we made considerable progress towards improving our sheep research facilities by acquiring new in-house sheep crates for feeding trials, redesigning pasture and paddock layouts, gate access, and fencing setups. These changes will have a positive impact on our long-term ability to conduct research on forage-ecophysiological aspects mediated by grazing livestock. We also expanded native grass plantings (+10 acres) with various mixes (big bluestem, eastern gamagrass, indiangrass, little bluestem, and sideoats grama) to conduct forage and livestock research in coming years. This area was laid out similarly to existing paddocks by including shade trees on both ends. Some shade trees were planted in spring of 2022 and plantings will resume in fall in the remaining places. Tree species were selected with help from a collaborator and included oak, sycamore, maple, cypress, and hackberry. We were able to acquire several soil probes to simultaneously measure moisture, temperature, and electric conductivity which we are using in a silvopasture project to evaluate establishment success and production of cool season perennial forages in a thinned hardwood forest. We also acquired a new 125-hp tractor through funds of the University of Arkansas Division of Agriculture – Agricultural Experiment Station.

3. Unique Project Related Findings:

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

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

We will conclude a major silvopasture project in the fall of 2022. Tall fescue and orchardgrass were less affected by woody, low-growing vegetation than we would have expected in this relative light-poor environment. Groundcover from both grasses held back typical forest floor vegetation by maintaining cover year-round. Reproductive tillers in both grasses were not observed until the second year after planting (2021-2022).

4. Accomplishment Summaries:

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

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

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

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

Developed first ever continuous soil property maps on Tribal Lands. Knowledge, data, and understanding is key for advancing agriculture and society, although not all sectors of U.S. societies have received information and technology transfer at the same rate. Tribal Reservations have very basic agronomic information relative to other producers in the U.S. This research created first ever high-resolution digital maps of soil properties on 22,880-ha for sustainable soil resource management. It is expected that these maps and future versions will be useful for soil, forage crop, and land-use decisions at the farm and Tribal-level for increased agricultural productivity and economic growth. Research was funded by the Foundation for Food and Agriculture Research.

During 2021-2022, two agroforestry-related projects were continued: 1) assessment of annual and perennial forages in thinned pine tree plantations and 2) establishment of perennial forages in a thinned native hardwood forest. Forages were selected based on previous research and experience from participating landowners. We are continuing a NIFA-funded project on the effects of polyphenolic compound-containing forage diets on sheep intake and effects on soil quality parameters including nitrogen leaching and ammonia emissions after the application of sampled urine from these sheep on 45-cm long soil cores. Leachate from these cores is being measured at various depth and obtained with small lysimeters that were placed inside the cores. Soil cores were obtained from an existing novel-endophyte tall fescue pasture with a Giddings sampler and transferred to the greenhouse. Sheep urine applications will be based on the concentration of hippuric acid with a total amount of 50 g N/m2.

5. Impact Statements

During 2021-2022, 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 on Tribal and non-Tribal pasture systems. 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 2021-2022 is included at the end of this document. Selected project impacts are listed above in detail.

1. Developed first ever continuous soil property maps on 22,880-ha Tribal Lands.

2. Identified pasture best management practices of sub-surface applications of nutrients and pasture aeration for minimizing nutrient losses to the air, soil, and water by 75%.

3. Quantified that tractor guidance can reduce input use by 10-20% and save U.S. producers $10.8-13.5 million per year by increasing equipment efficiency gains in pasture systems.

4. Used machine learning to tease apart driving factors in silvopastoral systems and found that soil nutrient distribution patterns drove grazing response, with animal grazing preference also being influenced by aboveground (forage and tree), soil, and landscape attributes.

5. Decomposition of forage root C affects potential soil C pools as the root system of grasslands accounts for up to 60% of C entering soils with native grass roots decomposing quicker than non-native forages.

**Issue:**

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

**Action:**

We secured funding for 4 years (2018 – 2023) to feed sheep with high- and low-tanning containing alfalfa/lespedeza silages as those will affect the amount of nitrogen converted in the rumen vs. bypass protein for digestion in the lower gut. Feces and urine were collected while 80 field plots were established in an existing tall fescue pasture to measure nitrous oxide, methane, carbon dioxide, and ammonia emissions and measuring nitrate leaching in soil cores of different diameters to which urine and a slurry of urine and feces that were applied in two different experiments in fall of 2018 and spring/summer 2019. Over the past several years, we conducted experiments on soil nitrate leaching, microbial activity, and ammonia emissions after the application of sheep urine and feces on various native and non-native perennial forages.

**Impact:**

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

6. Published Written Works

Refereed publications

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

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

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

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

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

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

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

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

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

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

Adams, T.C., A.J. Ashworth, and T. Sauer. 2021. Soil CO2 evolution is driven by forage species, soil moisture, grazing pressure, poultry litter fertilization, and seasonality in silvopastures. Agrosystems, Geosciences & Environment. 4:e20179. doi.org/10.1002/agg2.20179

Richwine, J.D., P.D. Keyser, D.W. Hancock, and A.J. Ashworth. 2021. Using a browntop millet companion crop to aid native grass establishment. Agronomy Journal. 113: 3210−3221. doi: 10.1002/agj2.20739

Adams, T.A., A.J. Ashworth, P.R. Owens, M. Popp, P.A Moore, and J. Pennington. 2021. Pasture conservation management effects on soil surface infiltration in hay and grazed systems. Journal of Soil and Water Conservation. 00182. doi.10.2489/jswc.2022.00182

Fuentes, B. A.J. Ashworth, M. Ngunjiri, and P.R. Owens. 2021. Mapping soil properties to advance the state of spatial soil information for greater food security on US Tribal Lands. Frontiers in Soil Science. 1, 95386. doi.org/10.3389/fsoil.2021.695386

Ashworth, A.J., T.C. Adams, T.P. Kharel, D. Philipp, P.R. Owens, and T.J. Sauer. 2021. Root Decomposition in Silvopastures is Influenced by Grazing, Fertility, and Grass Species. Agrosystems, Geosciences & Environment. 4:e20190. doi.org/10.1002/agg2.20190 (Cover Article)

Ylagan, S., H.C.S. Amorim, A.J. Ashworth, T. Sauer, B.J. Wienhold, P.R. Owens, Y.L. Zinn, and K.R. Brye. 2021. Soil quality assessment of an agroforestry system following long-term management in the Ozark Highlands. Agrosystems, Geosciences & Environment. 4:e20194. doi.org/10.1002/agg2.20194

Gurmessa, B., S. Cocco, A.J. Ashworth, E.F. Pedretti, A. Ilari, V. Cardelli, F. Fornasier, M.L. Ruello, and G. Corti. 2021. Post-digestate composting benefits and the role of enzyme activity to predict trace element immobilization and compost maturity. Bioresource Technology. 338,125550. doi.org/10.1016/j.biortech.2021.125550.

Kharel, T.P., A.J. Ashworth, P.R. Owens, D. Philipp, A.L. Thomas, and T. Sauer. 2021. Teasing apart silvopasture system components using machine learning for optimization. Soil Systems. 5, 41. doi.org/10.3390/soilsystems5030041

Gurmessa, B., V. Milanovic, E.F. Pedretti, L. Aquilanti, G. Corti, S. Cocco, A.J. Ashworth, I. Ferrocino, and M.R. Corvagli. 2021. Post-digestate composting shifts microbial composition and degrades antimicrobial resistance genes. Bioresource Technology. 340, 125662. doi.org/10.1016/j.biortech.2021.125662.

Adhikari, K., I.S. Braden, P.R. Owens, A.J. Ashworth, and C.P. West Relating topography and soil phosphorus distribution in litter-amended pastures in Arkansas. 2021. Agrosystems, Geosciences & Environment. 4:e20207. doi.org/10.1002/agg2.20207

Popp, M., K.R. Lindsay, A.J. Ashworth, P.A. Moore, Jr., P.R. Owens, T.A. Adams, M. Welsh, D. Pote, and J. Pennington. Economic and GHG emissions changes of aeration and gypsum application. 2021. Agriculture, Ecosystems & Environment. 321. 107616. doi.org/10.1016/j.agee.2021.107616

Katuwal, S., A.J. Ashworth, and P.R. Owens. 2021. Preferential flow under high-intensity short-duration irrigation events in soil columns from a karst and non-karst landscape. Vadose Zone J. 20:6. e20160. https://doi.org/10.1002/vzj2.20160

Jiang, Zhuodong, P.R. Owens, A.J. Ashworth, B.F. Ponce, A.L, Thomas, and T. Sauer. 2021. Evaluating tree growth factors into species-specific functional soil maps for improved agroforestry system efficiency. Agroforestry Systems. doi.org/10.1007/s10457-021-00693-9

Ashworth, A.J. and C. Nieman. 2022. Evaluating optimum seeding distances from subsurface banding poultry litter in crop rotations. Agricultural & Environmental Letters. 7: e220063. https://doi.org/10.1002/ael2.20063

Keyser, P.D. and A.J. Ashworth. 2022. Wheat cover crop and seed treatment for improving native warm-season grass establishment. Crop, Forage, & Turfgrass Management. 8, e20147. doi.org/10.1002/cft2.20147 e20147.

Kharel, T.P., A.J. Ashworth, and P.R. Owens. 2022. Linking and sharing technology: partnerships for data innovations for management of agricultural big data. Data. 2: 12. doi.org/10.3390/data7020012

Zhou, V., J.A. Larson, V.R. Sykes, A.J. Ashworth, and F.L. Allen. 2022. Long-Term Conservation Agriculture Effects on Corn Profitability in West Tennessee. Crop Science. 62, 1348– 1359. doi.org/10.1002/csc2.20727

Ashworth, A.J., S. Katuwal, P.A. Moore, Jr., and P.R. Owens. 2022. Multivariate evaluation of watershed health based on longitudinal pasture management. Science of the Total Environment. 824, 153725. doi.org/10.1016/j.scitotenv.2022.153725.

Bagnall, DK., C. L.S. Morgan, M. Cope, G.M. Bean, SB. Cappellazzi, K.L.H. Greub, D. Liptzin, C.E. Norris, E.L. Rieke, P.W. T. Ezra Aberle, A.J. Ashworth, et al. 2022. Carbon-sensitive pedotransfer functions for plant available water. Soil Science Society of America Journal. In press.

Ashworth, A.J., T.C. Adams, and A. Jacobs. 2022. Long-term sustainability implications of diverse commercial pollinator mixtures for the conservation reserve program. Agronomy. 12, 549. doi.org/10.3390/agronomy12030549.

Ashworth, A.J., C. Nieman., T.C. Adams, J. Franco, and P.R. Owens. 2022. Subsurface banding poultry litter influences edamame yield, forage quality, and leaf greenness. Agronomy Journal. 0, 1– 9. doi.org/10.1002/agj2.21048

Ashworth, A.J., T. Kharel, T.J. Sauer, T.C. Adams, D. Philipp, A. Thomas, and P.R. Owens,

Spatial monitoring technologies for coupling the soil plant water animal nexus. 2022. Scientific Reports. 12, 3508. doi.org/10.1038/s41598-022-07366-2

Amorim, H.C.S., A.J. Ashworth, T.J. Sauer, and Y.L. Zinn. 2022. Soil organic carbon and fertility based on tree species and management in a 17-year agroforestry site. Agronomy. 12, 641. doi.org/10.3390/agronomy12030641

Rieke, E.L., S.B., Cappellazzi,M. Cope, G.M. Bean, K.L.H. Greub, C.E. Norris, P.W. Tracy, E. Aberleb, A.J. Ashworth, et al. 2022. Linking soil microbial community structure to potential carbon mineralization: A continental scale assessment of reduced tillage. Soil Biology and Biochemistry. 168, 108618. doi.org/10.1016/j.soilbio.2022.108618.

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. 2022. Relationships between land use and stream chemistry in the Mulberry River Basin, Arkansas. River Research and Applications. In press.

Lee, J.T. Lee, A.J. Ashworth, M.T. Kidd, A. Mauromoustakos, and S.J. Rochell. 2022.

Evaluation of a threonine fermentation product as a digestible threonine source in broilers,

J. of Applied Poultry Research, 31, 100252, doi.org/10.1016/j.japr.2022.100252.

Ashworth, A.J., B. Putman, T. Kharel, G. Thoma, A. Shew, M. Popp, and P.R. Owens. Impact assessment of tractor guidance systems based on pasture management scenarios. American Society of Agricultural and Biological Engineers. In press.

Katuwal, S., A.J. Ashworth, and P.R. Owens. 2022. Preferential transport of phosphorus from surface-applied poultry litter in soils from karst and non-karst landscapes. Soil Science Society of America Journal. 00, 1– 13. https://doi.org/10.1002/saj2.20424

Bagnall, DK., C. L.S. Morgan, M. Cope, G.M. Bean, SB. Cappellazzi, K.L.H. Greub, D. Liptzin, C.E. Norris, E.L. Rieke, P.W. T. Ezra Aberle, A.J. Ashworth, et al. Selecting soil hydraulic properties as indicators of soil health: measurement response to management and site characteristics. Soil Science Society of America Journal. In press.

Ashworth, A.J., P.A. Moore, Jr., T. Bacon, K. Anderson, and J. Martin. Twenty-year phosphorus trends in forage systems receiving aluminum sulfate treated poultry litter. American Society of Agronomy Journal. In press.

Liptzin, D., C.E. Norris, S.B. Cappellazzi, G.M Bean, M. Cope, K.L.H. Greub, E.L. Rieke, P.W. Tracy, E. Aberle, A.J. Ashworth, et al. 2022. Carbon indicators of soil health in long-term agricultural experiments. Soil Biology and Biochemistry, 172, 108708. doi.org/10.1016/j.soilbio.2022.108708.

Niyigena, Valens; Ashworth, Amanda J; Nieman, Christine; Acharya, Mohan; **Coffey, Ken; Philipp, Dirk**; Meadors, Lillian; Sauer, Tom. 2021. *Factors affecting sugar accumulation and fluxes in warm- and cool-season forages grown in a silvopastoral system*. Agronomy 11:354.

A.J. Ashworth, T.C. Adams, T.P. Kharel, **D. Philipp**, P. Owens, and T. Sauer. 2021. *Root decomposition in silvopastures is influenced by grazing, fertility, and grass species*. Agrosyst Geosci Environ;4:e20190. 190. https://doi.org/10.1002/agg2.20190

Tulsi Kharel Amanda J. Ashworth, Phillip R. Owens, **Dirk Philipp**, Andrew L. Thomas, and Tom Sauer. 2021. *Teasing apart silvopasture system components*. Soil Syst. 5(3), 41. <https://doi.org/10.3390/soilsystems5030041>

V. Niyigena, **K. P. Coffey**, W. K. Coblentz, **D. Philipp, R. T. Rhein**, J. D. Caldwell, and B. C. Shanks. 2021. *Nitrogen balance and blood urea nitrogen by gestating sheep offered alfalfa silage wrapped with or without an enhanced oxygen barrier plastic after time delays up to three days.* Small Ruminant Research, Vol. 198, 106355. <https://doi.org/10.1016/j.smallrumres.2021.106355>

Christine C. Nieman, **Kenneth P. Coffey**, Ashley N. Young**, Elizabeth B. Kegley**, Paul Hornsby, Jimmie Hollenback, **Dirk Philipp**. 20XX. *Intake, digestibility, and rumen fermentation by lactating beef cows offered bermudagrass hay with different sources of dried distillers grains.* Applied Animal Science (under revision).

Amanda J. Ashworth, Tulsi Kharel, Tom Sauer, Taylor C. Adams, **Dirk Philipp**, Andrew L. Thomas, and Phillip R. Owens. 20XX. *Spatial Monitoring Technologies for Coupling the Soil Plant Water Animal Nexus*. Scientific Reports (under revision)

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

Other publications

Ashworth, A.J., and C. Neiman. 2022. Subsurface Banding Litter Reduces Nutrient Losses and Improves Yields. Crop, Soils, Agronomy News. May, Issue; pg. 22.

Ashworth, A.J., S. Ylagan, H. Amorim, P.R. Owens, and T.J. Sauer. Agroforestry, Poultry Litter, and Soil Health. 2022. Features Article in Soil Science Society of America, American Society of Agronomy, and Crop Science Society of America News. https://doi.org/10.1002/csan.20637

Ashworth, A.J., T.C. Adams, T.P. Kharel, D. Philipp, P.R. Owens, and T.J. Sauer. 2021. What drives roots’ decomposition and carbon storage in grassland soils? <https://soilsmatter.wordpress.com/2021/11/01/what-drives-roots-decomposition-and-carbon-storage-in-grassland-soils/>

**Ally Grote, Allison Morgan, Ken Coffey, Christine Nieman, Dirk Philipp, Elizabeth Kegley.** 2021. *Using tannins to mitigate tall fescue toxicosis.* ASAS Annual Meetings. <https://doi.org/10.1093/jas/skab235.847>

**Esmeka Parkes, Mary Cathleen Savin, Dirk Philipp, Ken Coffey.** 2021. *Examining Nitrogen Retention and Nitrogen Loss from Grasslands Receiving Manure from Ruminants Consuming Tannin Supplemented Tall Fescue*. ASA-CSSA-SSSA Annual Meeting, Salt Lake City.

**Janorschke, M., M. Savin, D. Philipp**, C. Nieman., **M. Bertucci**, A. Ashworth, **D. Miller**. 2021. *Evaluating short-term influences of silvopasture systems establishment on soil health within three basal areas and two forages*. ASA-CSSA-SSSA Annual Meeting, Salt Lake City.

**Maddala, S., M. Savin, D. Philipp**. 2021. *Drawing parallels: Coupling in situ soil N fluxes with microbial functional gene abundances.* ASA-CSSA-SSSA Annual Meeting, Salt Lake City.

**Maddala, S., M. Savin, D. Philipp**. 2021. *Temporal effects of rewetting a grassland soil on nitrate and ammonium flux over a 120-hour period*. ASA-CSSA-SSSA Annual Meeting, Salt Lake City.

Proceedings publication

Bulletins and Extension Factsheets

**Philipp, D.** (2021). Strategies for native grass establishment. UA Division of Agriculture.

**Philipp, D.** (2021). Native perennial warm season grasses require a flexible approach to weed control. UA Division of Agriculture.

**Philipp, D.** (2021). Silvopastoral Systems may hold key for climate resilience. UA Division of Agriculture.

**Philipp, D.** (2021). Keeping cattle cool and productive during the hot summer months. UA Division of Agriculture.

**Philipp, D.** (2021). Native perennial warm season grasses on beef farms. AR Cattlemens’ Association

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

**Philipp, D., Hightower, M.** (2021). Grazing area upkeep an issue

* Arkansas Democrat Gazette
* Pine Bluff Commercial

**Philipp, D., McGeeney, R.** (2021). Wet weather offers challenges for cow and calf industry

* Carrol C. News
* Ashley News Observer
* Harrison Daily Times
* Pine Bluff Commercial
* Arkansas Democrat Gazette

**Philipp, D., McGeeney, R.** (2021). Making the most of manure in pastures

* Cherokee Village Villager Journal
* Batesville Daily Guard
* Salem News

**Philipp, D., Hightower, M.** (2021). Moving your pasture towards the desired forage species

* Harrison Daily Times
* Johnson Co. Graphic
* Nashville News Leader
* Heber Springs Sun-Times

**Philipp, D., McGeeney, R.** (2021). Manage cool-season-perennial grasses for a successful grazing season.

* Pine Bluff Commercial
* Johnson Co. Graphic
* Flippin Mountaineer Echo

**Philipp, D., McGeeney, R.** (2021). Division of Agriculture forage expert to serve as co-investigator for $1 million sustainability grant.

* Pine Bluff Commercial

**Philipp, D., McGeeney, R.** (2021). Plan head for fall management of pastures

* Hope Prescott News
* Johnson Co. Graphic
* Batesville Daily Guard

**Philipp, D., McGeeney, R.** (2021). Moving sheep frequently benefits animal health, cool-season-forages.

* Johnson Co. Graphic
* Batesville Daily Guard

**Philipp, D., Shelby S., Lovett, J.** (2021). Guardian llama protects flock of sheep at research farm.

* RFD TV
* 5Newsonline

**Savin, M., Coffey, K., Philipp, D., Zhao, J., Miller, F. (**2021). News report on current research activities.

**Philipp, D., Courage, T.** (2021). Management of native grasses doesn’t stop during winter time.

**Philipp, D., Courage, T.** (2021). Drought and rain – a closed canopy will help cope with both

**Philipp, D., Courage, T**. (2021). Weed control in native grasses requires flexible approach

6. Scientific and Outreach Presentations

Invited presentations

By request of ARS’ Office of Outreach, Diversity, and Equal Opportunity, present at the USDA-ARS National Native American Heritage Month Theme: Together Towards Tomorrow, "Tribal Soil Systems: Challenges and Opportunities for Digital Agriculture" November, 2021.

Invited to present at a USDA Interagency Resilience Assessment in Central America - Northern Triangle - Climate change aimed at addressing on November, 2021 in support of the U.S. Strategy for Addressing the Root Causes of Migration in Central America (Pillar I: Addressing economic insecurity and inequality; Strategic Objective 4: Build Resilience to Address Climate Change and Food Insecurity).

Invited by the Natural Resource Conservation Service, Arkansas Grazing Specialist to present “Benefits of soil microbial diversity in organic and conventional pastures” to farmers, farm consultants, industry personnel, and NRCS staff, 2021.

Invited by the Institute of Geographical Information System, School of Civil and Environmental Engineering to present "Data-driven Technology Applications for Improved System Sustainability" to the National University of Sciences and Technology International Seminar Series. Islamabad, Pakistan, 2021.

Systems-level Evaluations for Coupling the Soil Plant Water Animal Nexus to the Federal Rural Lavras, Brazil Graduate Program in Soil Science International Seminar Series, 2021.

Abstracts , symposium and conference presentations

Katuwal, S., A.J. Ashworth, P.A. Moore Jr., K. Brye, M. Schmidt, M. Vanotti, and P.R. Owens. 2021. Preferential transport of phosphorus from surface-applied poultry litter in soils from karst and non-karst landscapes Soil Science Society of America. [CD-ROM]. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (ASA, CSSA, and SSSA), International Meetings, Madison, WI. (Poster Presentation).

Ashworth, A.J., Gurmessa, B., K. Adhikari, P.R. Owens, T. Sauer, and G. Corti. 2021. Soil microbiome is driven by terrain attributes and forage species in silvopastoral systems. [CD-ROM]. ASA and CSSA, International Meetings, Madison, WI. (Poster Presentation).

**Philipp, D**., Webinar - Cattle Production Workshop, "Pasture Management," University of Arkansas - Pine Bluff, Online. (2021).

**Philipp, D**., Webinar - Cattle Production Workshop, "Beef cattle and winter management," University of Arkansas - Pine Bluff, Online. (2021).

7. Collaborative Funded Grants

Funded 2021-2022

2022 USAID, "Supporting Vulnerable Smallholder Communities during Climate Change Through Improving Soil Nutrition for Grain and Coffee Production", $56,000 for 2022-2024 with with Amanda Ashworth, Phillip Owens, and Axel Schmidt, PI ($56,000 Ashworth portion).

2022 USDA-Agricultural Research Service funding Opportunity in Antimicrobial Resistance, “Scaling up Potential AMR and Phage Transport to Groundwater in Karst Geologies Through Digital Tools” $69,202 for 2022-2024 with Amanda Ashworth, Mary Savin, Lisa Durso, Phillip Owens, Sheela Katuwal, and Jennifer DeBruyn, PI ($69,202 Ashworth portion).

2022 AFRI Foundational Knowledge of Agricultural Production Systems, entitled “Coupling Human and Machine Knowledge To Optimize Tribal Food Systems", $649,684, PI ($293,167 Ashworth portion).

2022 AFRI Sustainable Agricultural Systems, entitled “Fostering Resilience and Ecosystem Services in Landscapes by Integrating Diverse Perennial Circular Systems", $10,000,000, Co-PI. ($277,777 Ashworth portion).

2021 USDA-NIFA Organic Agriculture Research and Extension Initiative, "Advancing Organic Agriculture in the Mid-South: Evaluating Systems and Reducing Barriers to Entry", $1,267,813, Co-PI.

2021 US Geological Survey, Arkansas Water Resource Grant, “Quantifying Bypass Flow in Terra Rosa Soils: Implications for Groundwater and Stream Contamination” $18,537, Co-PI.

Ongoing

2020 Conservation Innovation Grants (CIG) On-Farm Conservation Innovation Trials (On-Farm Trials), entitled “Improving the Economic and Ecological Sustainability of US Crop Production through

On-Farm Precision Experimentation,” $5,000,000 ($125,735 Ashworth portion).

2020 ARS-Office of Technology Transfer, Innovation Fund, entitled “Traditional Soil Knowledge to Technology,” $25,000 for 2020-2021 with Amanda Ashworth and Phillip Owens, PI.

2020 AFRI Sustainable Agricultural Systems, entitled “Systems-based Integrated Program for Enhancing the Sustainability of Antibiotic-restricted Poultry Production,” $10,000,000 ($65,780 Ashworth portion) for 2020-2025, Co-PI.

2020 ARS-Office of Technology Transfer, Innovation Fund, entitled “Quantifying Macropore Flow and Nutrient Leaching in Soil Column Representing Different Land-uses in Karst Landscapes,” $35,000 for 2020-2021 with Amanda Ashworth, Matias Vanotti, Phillip Owens, and Philip Moore, PI.

* Rupp, S. et al. (Philipp Co-PI): A holistic, cost-effective approach for reinvigorating practice 360 (waste facility closure) for poultry houses in Northwest Arkansas.
	+ USDA-NRCS/CIG, $150,000
* Morris, M. et al. (Philipp Co-PI): Soil for Water.
	+ USDA-Southern SARE; $1,000,000
* Richardson et al. (Philipp Co-PI): Developing a sustainable approach to roadside vegetation management in the State of Arkansas
	+ Arkansas Department of Transportation; $350,000
	+ Jagadamma, S. et al. (Philipp Co-PI): Native Warm Season Perennials: An Enduring Solution To Summer Drought And Slump For Fescue Belt Organic Forage Production
		- USDA, Organic Agriculture Research & Extension Initiative; ~$105,000
1. Graduate Students
* Matt Janorschke, MS Student co-advised with Dr. Mary Savin (Univ. of Arkansas, Crop and Environmental Sciences)
* Ethan Collins, MS Student (Univ. of Arkansas, Crop and Environmental Sciences)

**Oregon**

1. Impact Nuggets

Development of new methodology or approaches:

• Utilizing molecular biology techniques to identify alfalfa forage quality genes (Guojie Wang; regional grant project).

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

• Using climate and soil factor spatial data layers to map forage species suitability zones (David Hannaway)

Implementation of solutions or adoption of recommendations developed:

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

• Developing a Species Selection web segment based on matching climate and soil conditions with quantitative forage species tolerances.

Cleaner environment and healthier communities:

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

2. New Facilities and Equipment: NA.

3. Unique Project Related Findings: NA.

4. Accomplishment Summaries

International Collaborative Efforts: Participation in International lucerne (alfalfa) modeling working group with scientists from New Zealand (Lincoln University and Plant & Food Institute), Australia (APSIM modeling group), Argentina and Chile (workshop participants) (David Hannaway0.

National Collaborative Efforts: Submitted proposal to USDA Alfalfa and Forage Research Program entitled “Modeling and Mapping Alfalfa Fall Dormancy and Winter Survival Index Types for Optimized Cultivar Selection.” Collaboration includes NCCC-31 participant David Hannaway, PRISM Group scientists Chris Daly and Michael Halbleib, New Mexico alfalfa scientist Leonard Lauriault, and numerous US alfalfa Extension and research scientists.

Oregon Collaborative Efforts: Oregon State University Extension and Research faculty working together through a “Forage and Livestock Systems” Extension (and Research and Teaching) Working Group. The mission of this work group is to increase collaboration on planning and execution of high priority projects and contributing to the many integrated scientific disciplines involved in sustainable forage-livestock systems. Recent progress includes development of 11 forage species draft fact sheets (David Hannaway, Guojie Wang, Serkan Ates, and Gordon Jones).

 The “Oregon Forages” website (https://forages.oregonstate.edu/oregon) is being developed to present comprehensive content of forage and livestock system topics and segments devoted to the interrelationships among soil, water, plant, animal, and human health and the economic and social implications of sustainable agricultural systems. This site simplifies the search for information by county agents and specialists, farmers and ranchers, and agricultural agency personnel and builds stronger linkages among research, outreach, and classroom and eCampus teaching efforts (Working Group participants).

o Progress to date includes developing the organizational outline of 19 topic areas, numerous sub-topics, and content authors. Initial drafts have been completed for many of the sections and a review process is being developed. This review process is necessary for ensuring “scholarly accomplishments” credit for authors.

o Funding from the Extension Program Leader has been used to continue development of drafts for 11 annual forage fact sheets and initial drafts for numerous other species.

o A uniform template includes: Description and Uses, Identification, Cultivar Types, Suitability Zones, Suitability Maps (based on quantitative tolerances and GIS gridded data), Seasonal Production Profiles, Phenological Development (Bloom time for legumes), Establishment and Management, Quality and Antiquality, Image Gallery, Resources, Authors, Reviewers, and Funding Support. Internal and external reviews have been solicited, received, and incorporated.

o The primary challenges remaining for completion of these fact sheets include the Seasonal Production Profiles and Phenological Development graphics based on photo-thermal time. University scientists and seed industry personnel are working together to develop a maturity index for cool-season grasses with several national field sites.

Research: PI and Project Descriptions

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

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

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

5. Published Written Works

Refereed Publications

Li Zhensong, Feng He, Zongyong Tong, Xianglin Li, Qingchuan Yang, and David B. Hannaway. 2022 (preprint, under review). Metabolomic changes in crown of alfalfa (Medicago sativa L.) during de-acclimation. https://doi.org/10.21203/rs.3.rs-1515778/v1

Extension Publications

 Under Development

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

Hannaway, David B. et al. 202X. Annual Forages Fact Sheet Series. Oregon State Univ. Extension Ser.

McGregor, Ian, David. B. Hannaway, Leticia Henderson, Cassie Bouska, Linda Brewer, Scott Duggan, Amy Derby, Pete Schreder, and Mylen Bohle. Forage ID Guidebook. 202X. Forage-Livestock Systems Working Group Project publication. Oregon State Exten. Ser.

Bohle, Mylen, David Hannaway, Bill Buhrig. 202X. Irrigating Alfalfa. Beef Cattle Library. Oregon State University.

6. Scientific and Outreach Presentations:

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

7. Collaborative Grants

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

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

**North Dakota**

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 increases the delivery of ecosystem services, enhances resilience and stability.

2. New Facilities and Equipment:

None

3. Unique Project Related Findings:

4. Accomplishments summaries:

Alfalfa-corn intercropping: We have continued with the research in alfalfa-corn intercropping systems started in 2014. In these new experiments, we tested alfalfa alone, corn (for grain) alone at 76- and 152-cm row spacings and corn intercropped with alfalfa at 76- and 152-cm row spacings. The overall scale of success of these treatments is measured in corn grain yield in the first year and alfalfa establishment and forage yield in the second year. When years and locations were combined, corn alone with 152-cm row spacing yielded 17% less grain than corn alone with 76-cm row spacing, however, when comparing intercropped treatments, corn with 152-cm rows yielded 23% less than corn with 76-cm rows. The presence of alfalfa did not affect corn yield with either corn row spacing. Data collected on each experimental unit also includes measurements of soil gravimetric water content, intercepted photosynthetically active radiation by the crop canopy, and multispectral indices recorded with an unmanned aerial vehicle. The data sets collected over this two-year study will allow for more specific recommendations regarding alfalfa-corn intercropping. Optimizing this specific cropping system for growers in the northern Great Plains could increase profitability as well as forage nutritive value and crop efficiency.

Identify AM fungal communities (AMF) a in alfalfa populations in North Dakota and South Dakota

The arbuscular mycorrhizae fungi (AMF) colonization percentage ranged from 12% to 88% (average of 40.3%) and from 18.2% to 82.2% (average of 53.4 %) in the root samples from North Dakota and South Dakota, respectively. The results of the multiple linear regression analysis of the SD samples showed no significant effect of the explanatory variables on AM fungal colonization. In order to avoid an inaccurate estimation of variance due to multicollinearity among explanatory variables, a variation factor (VIF) analysis with a cut-off value of >10 was used to exclude variables that showed multi-collinearity.

By contrast, the North Dakota samples showed a significant effect of grazing and irrigation on the AM colonization at p≤0.05. Plant density also influenced the AM colonization at p< 0.1. Grazing, irrigation, and plant density were subsequently tested alone in simple regression models. Grazing had a significant positive effect on AM colonization percentage (Adj R2 = 9.2%, p< 0.1). However, the effect of plant density and irrigation effect was not found to be significant when tested alone. In general, livestock grazing has a negative effect on AM abundance. Grazing decreases the above-ground biomass, and thereby reduces the carbon supply for the AM fungus that is necessary to expand its soil mycelium. However, this effect depends on the grazing intensity. Heavy grazing has a strong effect on AM abundance, while light grazing has no significant effect (Yang et al. 2020). Depending on plant density, AM benefits for the host plants can differ. Duan et al. (2021) for example observed that high plant densities can increase the shoot biomass, grain yield and water use efficiency of wheat.

Establishment of alfalfa in intercropping with sunflower at two row spacings

Intercropping is a way to better utilize the growing season and available resources more profitably. The integration of alfalfa into crop rotations may also lead to a reduction of synthetic nitrogen use and losses by leaching or run-off. This research evaluated the possibility of intercropping alfalfa with sunflower (Helianthus annuus L.) in the northern Great Plains using a randomized complete block design to establish alfalfa for the subsequent crop year. This approach could increase alfalfa forage yield and nutritive value in the second year while providing a sunflower crop during the normally low-producing alfalfa establishment year. Treatments were alfalfa alone, sunflower alone at 76.2- and 152.4-cm row spacing, and sunflower intercropped with alfalfa at 76.2- and 152.4-cm row spacing. Sunflower achene yield in the first year was measured and no significant differences among treatments were determined in 2021. Alfalfa forage yield and nutritive value was also measured and calculated in 2021, along with measurements of soil gravimetric water and light interception. There was an interaction between treatments and date for light interception. This was mainly because alfalfa alone had much lower light interception than all treatments with sunflower. Gravimetric water was lower in soil where alfalfa and sunflower were intercropped. In-row alfalfa dry biomass and quality were not significantly different for the 76.2- or 152.4-cm sunflower row spacings.

Identification of rhizobium inoculants tailored for performance with new alfalfa varieties and diverse soil types (Barney Geddes, NDSU microbiology)

Objective 1 was to establish a strain collection from ND soils.186 rhizobia were isolated from 500 nodules from 23 sample locations in 2021 (same as for AMF). Second sample trip in 2022 was done to isolate more (goal = 500 rhizobia).Soils data included acidic pH, salinity, N,PK, others. Generally acidic pH and high soil nitrogen content resulted in less nodules.

Objective 2 was to adapt Plasmid-ID screening to S. meliloti/alfalfa. Plasmid-ID technology allows simultaneous screening of hundreds of rhizobia for effectiveness (ability to promote biomass) based on nodule fluorescence, and competitiveness (ability to form root nodules when competing with natural rhizobia) by identifying rhizobia in each nodule using next-generation sequencing. Functional in R. leguminosarum/ pea but not S. meliloti/ alfalfa. Developed new Plasmid-ID vectors for use in S. meliloti; new vector backbone that can function in S. meliloti, and new promoter expressing GFP (fluorescence).

Perennial grasses winter-hardiness evaluation:

Experiments were conducted using a randomized complete block design with four replicates. Experiments were sown on 1 May and 19 May 2020 in Fargo and Prosper, respectively. Several varieties of each of the following grasses were evaluated: Orchardgrass (4), meadow fescue (3), tall fescue (6), perennial ryegrass (PRG) (3), meadow brome (2), smooth brome (2), crested wheatgrass (CWG), intermediate wheatgrass (IWG), creeping wheatgrass (hybrid CWG x IWG), and a dryland mix, for a total of 24 treatments.

In general, winter survival was much greater in Fargo than in Prosper across species and varieties. There were not great differences among varieties within a same crop. Meadow and smooth brome have the highest survival of all grasses. Perennial ryegrass stands were evaluated twice. First stand evaluation was on 3 May when almost no plants showed any signs of survival in Prosper and only 8-15% survived in Fargo. In the second stand evaluation on 9 June, PRG survival increased up to 37% in Fargo and up to 20% in Prosper, with not clear significant differences among varieties.

In the seeding year, forage yield ranged from 1849 to 4124 kg/ha for the eight species tested. Meadow fescue had about 20% less yield than tall fescue averaged across all varieties. Smooth brome BAR BIF 1GRL had over 1120 kg/ha higher forage yield than the ‘Manchar’ check variety. Similarly, the creeping wheatgrass hybrid had over 1120 kg/ha higher yield than the Hycrest check variety

In 2021, first production year, due to the drought, grasses were harvested twice in the season. In the second harvest, one variety of meadow brome (Arsenal) in Fargo and two varieties of orchardgrass (Barlegro and Intensiv) and three varieties of tall fescue (STF-43-Mix, Armory, and 7FACF82) in Prosper exceeded 2000 lbs/acre yield).

The total seasonal yield, sum of both cuts, was the highest for both meadow brome varieties, smooth brome ‘Artillery’ and intermediate wheatgrass Oahe at Fargo. In Prosper, highest yielding varieties were intermediate wheatgrass ’Oahe’, and creeping wheatgrass ‘Hamann’. The variety Armory was the highest yielding tall fescue. In addition, ‘McBeth’ meadow brome, ‘Artillery’ smooth brome, and ‘Hycrest’ crested wheat grass exceeded 2.5 tons/acre total seasonal yield in Prosper. The lowest yielding grass was perennial ryegrass since it suffered extensive winterkill. Although Remington it seemed to have a slightly better survival and forage yield than the other two perennial ryegrass varieties in the trial at both locations

Forage sorghum and mixes for summer forage

A study was conducted with the objective to determine how different crops contribute to a forage mix. Twelve combinations including 17 species were sown early summer at Fargo, Hickson, and Streeter, ND. The nutritive value of annual forage mixes and monocrops varied across environments and between treatments. Monocultures of forage sorghum and forage pearl millet produced more biomass than annual forage mixes. The three most productive mixes in comparison to the others were hybrid brassica/oat/forage pea/forage sorghum x sudangrass/sweet sorghum blend/foxtail millet, turnip/forage sorghum x sudangrass/sweet sorghum blend/forage pea/hybrid brassicas/oat/faba bean/forage pea and forage sorghum x sudangrass/radish mix. The latter been the most cost-effective mix. Forage sorghum dominated annual forage mixes at a planting rate of 5.6 Mg/ha. Grasses produced more biomass than dicotyledonous species in all botanical mixes.

Life cycle assessment (LCA) of integrated cropping systems for food, feed, and energy:

About 15 million hectares of corn (Zea mays L.) are converted to ethanol in the USA yearly. Maize production requires high-inputs, especially chemical nitrogen fertilizer. Numerous LCA studies of maize ethanol production indicate that even ethanol is a renewable fuel; the heavy use of fossil-fuel derived inputs in maize production does not reduce greenhouse gases emissions. In addition, maize cultivation in monoculture or in short rotations with soybean [Glycine max (L.) Merr] has negative impacts to the environment, such as nitrate leaching, soil erosion, and nitrous oxide emissions. Perennial crops such as alfalfa (Medicago sativa L.) reduce annual disturbance of soil, which affects many biogeochemical cycles that are key to provide resilience and stability to agroecosystems. Alfalfa provides long-term sustainability contributing to the soil health of cropping systems by affording nitrogen credits to the following crops. In addition, alfalfa reduces nitrate leaching and soil erosion, increases biodiversity, critical habitat for wildlife, and soil carbon sequestration. The project objectives were to evaluate the impact of alfalfa-maize intercropping on soil organic carbon balance, soil nitrous oxide emissions, soil nitrate leaching and global warming potential. Four three-year crop sequences were evaluated. 1) Corn-soybean-corn (CSC); 2) alfalfa-alfalfa-alfalfa (AAA); 3) Corn-spring planted alfalfa-alfalfa (CAA); and 4) Corn with intercropped alfalfa-alfalfa-alfalfa (CAIAA). Corn crop was for grain. Modelling of C and N cycles were conducted with the Denitrification-Decomposition (DNDC) model. Corn residue was left in the field after each harvest. Soil organic carbon balance in Year 1 was greater for the CAIAA sequence since alfalfa in intercropping is not removed from the field the first year. In the second year, CAAIC had the lowest SOC balance due to the four harvests of alfalfa removed from the field on the second year. In the third year, SOC balances were positive for all sequences but greatest for the AAA in spite of four harvests. This is because in the third-year alfalfa’s root mass increases sequestering carbon deep in the soil. The SOC for the sum of the 3-years balance was greater for the CAIAC sequence.

Nitrous oxide emissions and nitrate leaching for the three-year sequence were the highest for the CSC system and significantly lower for the three sequences containing alfalfa. The main driver of emissions was the nitrogen fertilization added to corn.

The net global warming potential was negative for all sequences, indicating all sequences sequester carbon after three years. But the CAIC sequence had the lowest net GWP of -5973 kg of CO2 eq./ha while the CSC sequence only had -760 kg of CO2 eq./ha.

4. Impact Statement

The forage program at NDSU is the only program that provides non-biased information to farmers on the performance of forages and the environmental impact of them in ND. Forages acreage, without including CRP or native rangeland, was 3,421,122 acres in 2020. Forages are the third most important crop in acreage in ND after wheat and soybean. Diverse studies in alfalfa management conducted by this project have demonstrated that forage yield can easily be increased on average at least by 0.3 ton/acre/yr. Alfalfa acreage in ND in 2020 was 510,313 acres and alfalfa-grass mixtures were 754,400 acres. An increase in forage yield of only 0.3 tons/acre/year x 1,264,813 acres (alfalfa & alfalfa-grass) at $120/ton of hay equals an economic impact of $45,533,268/yr. Alfalfa-corn intercropping allows alfalfa to be established in the corn production year. This system increases alfalfa yield in Year 2 by 2.5 tons/acre compared with a spring-seeded alfalfa with a net profit of $80/acre. The acres of corn silage-alfalfa rotation in ND are about 150,000 acres x $80= $1,200,000 in monetary impact. This without considering that having alfalfa in rotation with corn might become part of the solution to current high N fertilizer prices. Nitrogen credits of alfalfa to corn can be up to 150 lbs/acre with a N fertilizer value at $1/lb and raising, this would be a potential saving of $150/acre in 1,901,262 acres of corn=$285,189,300.

With increasing energy prices, crops as forage sorghum might be of interest to the energy industry in the near future. Forage sorghum can easily yield up to 10 tons DM/acre at $30-50/ton for a biomass feedstock gross income from $300 to $500 per acre. In 2020, FS acreage was 48,886 acres increasing 27% from 35,843 acres in 2017. At a $50/ton value by 10 tons/acre (2 cuts) as feed, the economic impact equals $24,441,500/yr.

Cover crops acreage increased 89% from 2012 to 2017 in ND, with a total of 404,267 acres (NASS, 2018). Current data suggest adoption of cover crops keeps increasing. Legume cover crops planted after wheat in one of our studies reduced the need of fertilizing corn by 50 lbs N/acre, however more recent studies to estimate N credit to corn and sugarbeet did not show N credit although the N is in the system and will cycle back to the crops eventually. 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 10 lbs N/acre, the economic value of reducing the fertilization in all corn acres, 1,901,262 acres x 10 lbs N/acre saving x $1/lb N, is $19,012,262/year. Cover crops forage value can add $30/acre revenue by grazing. If only 1% of the wheat acreage (6,460,097 acres) was planted to cover crops for grazing after harvest, the economic impact would be $1,938,029/year.

In addition, both cover crops and perennial forages are part of the strategy to increase carbon sequestration in regenerative agriculture. Increasing the value of the land of producers that demonstrate their fields sequester carbon.

In summary the forages and cover crops research in my project has a great economic impact as more growers adopt forages and cover crops into their rotation. There is no doubt that forages and over crops will have a very important role in N2 fixation, C sequestration, C markets, resilience, and stability in the near future.

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5. Published written work

Peer-reviewed publications

1. Franco, J.G., M.T. Berti, J.H. Grabber, J.R. Hendrickson, C.C. Nieman, P. Pinto, D. van Tassel, and V.D. Picasso. 2021. Ecological intensification of food production by integrating forages. Agronomy 11, 2580. https://doi.org/10.3390/agronomy11122580

2. Picasso, V., M. Berti, K. Cassida. S. Collier, D. Fang, A. Finna, M. Krome, D. Hanaway, W. Lamp., A.W. Stevens. 2022. Diverse perennial circular forage systems are needed to foster resilience, ecosystem services, and socioeconomic benefits in agricultural landscapes. Grassland Res. doi: 10.1002/glr2.12020

Scientific and Outreach Presentations

1. Berti, M.T., A. Cecchin, J.V. Anderson, and S. Bibby. 2022. Intercropping maize and alfalfa: A cropping system to mitigate the negative environmental impact of maize for ethanol production in the USA. A review European Biomass Conference, Marseille, France 9-12 May 2022. (virtual)

2. Berti, M.T., 2022. Managing cropping systems to enhance ecosystem services delivery. 37th Plant Sciences Graduate Student Symposium. Winnipeg, MB, Canada, 4-5 March 2022. Invited keynote speaker

3. Berti, M.T. 2022. Modifying cropping systems management to mitigate environmental impact and increase ecosystem services delivery. Environmental and Conservation Sciences Seminar Series. North Dakota State University. 20 January 2022. Invited speaker

4. Wanchuk, M.D. McGranahan, K. Sedivec, and M.T. Berti. 2022. Forage nutrient composition responses to three different grazing systems. Society for Range Management Conference. Albuquerque, NM, 6-10 February.

5. Neubauer, M., M.T. Berti, S. Bibby, J.V. Anderson, and D.P. Horvath. 2021. How does intercropping of corn and alfalfa cause gene expression to vary? ASA-CSSA-SSSA International Annual Meetings, Salt Lake City, 7-10 November, 2021. (poster)

6. Mozea, K., M.T. Berti, K. Sedivec, S. Bibby, and M. Neubauer. 2021. Nutritive value and yield of annual forage mixtures for grazing. ASA-CSSA-SSSA International Annual Meetings, Salt Lake City, 7-10 November, 2021. (poster)

7. Bibby, S., M.T. Berti, A.F. Wick, D.P. Horvath, J.V. Anderson, A. Greenberg, K. Mozea, and M. Neubauer. 2021. Corn alfalfa intercropping with different row spacings. ASA-CSSA-SSSA International Annual Meetings, Salt Lake City, 7-10 November, 2021. (poster, 2nd place in R. Barnes competition)

8. Berti, M.T., J.V. Anderson, D. Samarappuli, and A. Cecchin. 2021. Can forage sorghum types be grown as feedstock for bioenergy in northern latitudes? Industrial crops and products unlocking the potential of bioeconomy. 32nd Annual Conference Association for the Advancement of Industrial Crops –University of Bologna, Italy, Sept. 5-9, 2021.

Other publications (magazines, extension/online/bulletins)

1. Berti, M.T., and M. Tabert. 2022. Establishing alfalfa while growing sunflower. Forage Focus Magazine. August 2022. Midwest Forage Association, St. Paul, MN. p. 2-3

2. Berti, M.T. and S. Bibby. 2022. Establishing alfalfa while growing corn. Progressive Forage Magazine. Issue 2, February 2022. p. 28-31

3. Berti, M.T. 2021. Management and alternative forages following a drought. Forage Focus Magazine December 2021. Midwest Forage Association, St. Paul, MN. p. 11.

4. Berti, M.T., and S. Bibby, 2021. Intercropping with different row spacings affects intercepted solar radiation. Forage Focus Magazine December 2021. Midwest Forage Association, St. Paul, MN. p. 17

7. Collaborative grants

1. Midwest Forage Association 05/2022-04/2023. Testing new high quality perennial cool-season forage grasses with improved winter hardiness and persistence: Year 3. $2,942, PI

2. ND Corn Utilization Council. 7/2022-6/2023-Research and Extension Efforts at the Soil Health and Agriculture Research Extension (SHARE) Farm-Logan Center, ND $64,258, co-PI

3. USDA-NIFA-SAS. 10/2021-9/2026. Fostering Resilience and Ecosystem Services in Landscapes by Integrating Diverse Perennial Circular Systems (RESILIENCE CAP). Award no. 2021-68012-35917; $9,999,978 (to my program $747,868). Agronomy Research lead, co-PD.

8. Graduate students

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

Haley Mosqueda, PhD. Establishing alfalfa with corn and sorghum. Expected graduation date May 2025. Advisor: Berti (Resilience-CAP)

Ryan Campbell, MS. Resilience and soil health differences on farms with or without perennials in their rotation. Expected Graduation date: May 2024. Advisor: Berti (Resilience-CAP)

McKayla Neubauer, MS Molecular changes in the transcriptome of alfalfa under intercropping with corn. Expected graduation December 2022. Advisor: Berti

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

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

Kenneth Mozea, MS: Full-season cover crops grazing mixtures. May 2021. Advisor: Berti.

Jonathan Spiess, PhD: Livestock responses to variable forage nutritive value on patch-burn grazing pastures in North Dakota. December 2021. Advisor: McGranahan.

**Maryland**

1.Impact Nugget

The beneficial biodiversity on farms, such as predators of insect pests, depends on the presence and locations of suitable habitats for their survival and reproduction. Predatory ground beetles, lady beetles, and dragonflies and damselflies are examples of those beneficial species. Our studies within forage crops, and the surrounding landscape, are designed to better understand their role in these ecosystems and their potential for conservation biological control.

2. New Facilities and Equipment

3. Unique Project Related Findings

We have discovered that lady beetle species are more abundant in leafhopper-susceptible cultivars than in leafhopper-resistant cultivars. While there were species found rarely through the months two species were collected on most of the sampling dates in both cultivars. Those key species are Coleomegilla maculata and Coccinella septempunctata. Studies are underway to determine why these species prefer the susceptible cultivars.

Agricultural drainage ditches sampled along Maryland’s Eastern Shore contain an abundant and ecologically diverse population of ground beetles. We are studying their movement into adjacent crop fields as a means to provide conservation biological control of insect pests.

Dragonflies and damselflies forage for and obtain a variety of prey in alfalfa. Here, by analyzing their feces, we detected prey from 20 families across five orders of insects.

Increasing nitrogen fertilizer application rates influenced triticale forage protein concentrations in a linear fashion irrespective of sulfur application, and this triticale forage was included in the ration for lactating dairy cows without affecting milk production.

Bred dairy heifers managed in an improved grazing system can achieve satisfactory growth relative to TMR-fed counterparts and are able to achieve acceptable gains to reach >87% of mature bodyweight prior to calving.

4. Accomplishment Summaries

Avenesyan, Alina, and William Lamp. Diverse host plants of the first Instars of the invasive Lycorma delicatula: Insights from eDNA metabarcoding. We investigated the host plant range of the first instar of the invasive spotted lanternfly, Lycorma delicatula (Hemiptera:Fulgoridae). In this study, we used a novel approach, utilizing “bulk” DNA extracts for DNA metabarcoding of nymphal gut contents, to identify all the detectable plants that the nymphs had ingested prior to being collected. The results of this work included the following: (1) high-quality amplicons (up to 406 bp) of a portion of the rbcL gene were detected and 27 unique ingested plant species belonging to 17 families were identified; (2) the results were published in journal Insects, Special Issue "Advances on Invasive Insect Pests: Insect Behavior, Host Plant Usage, Biocontrol, and More".

Smith, Darsy, and William Lamp. Seasonal pattern of pea aphid, Acyrthosipon pisum and three aphidophagous coccinellids in two alfalfa ecosystems: response to glandular trichome mediated resistance. The pea aphid is an oligophagous species that feed on several legume crops including alfalfa. In United States, alfalfa farmers grow cultivars with resistance to pea aphid, and other pests such potato leafhopper (Empoasca fabae) as a management practice. Potato leafhopper-resistant cultivars have glandular trichomes and, are one of the preferred cultivars since potato leafhoppers are the main alfalfa pests across the country. Although there is vast evidence that plant and crops with glandular trichomes can affect the behavior of natural enemies and increase mortality, the seasonal pattern, and interactions between non-target pests and their natural enemies is poorly understood in most of those systems. Our goal is to design ecological studies to address the interaction between glandular trichomes and non-target pests and its natural enemies under field conditions. To compare the seasonal pattern of pea aphid and its natural enemies in alfalfa ecosystems -with resistance and no resistance to potato leafhopper- we established a field study in a randomized complete block design with large plots of 100x100 feet of each alfalfa cultivar. From April to September in 2021 we placed sticky traps and collected weekly sweep samples through four growing periods. A total of seven aphidophagous coccinellid species were identified including the convergent ladybeetle (Hippodamia convergens), the pink spotted lady beetle (Coleomegilla maculata), and the seven-spotted ladybeetle (Coccinella septempunctata), in both alfalfa ecosystems. Weekly sampling of resistant and susceptible alfalfa with a sweep net in 2021 revealed significant reduced abundance of the seven-spotted ladybeetle, but no significant differences in pea aphid abundance in plots with resistant to potato leafhopper. While these results are from 2021, we will continue sampling in 2022-2023 to determine whether patterns in the abundance are similar. Trends through the four growing periods were similar in pea aphid and the seven-spot ladybeetle population with a peak abundance late in May, before the second cut of alfalfa in plots with resistant to potato leafhopper. Our findings will show the response of pea aphid, and abundant aphidophagous coccinellids to alfalfa cultivars with glandular trichomes; and will inform farmers and scientists about the potential long-term ecological impacts of host plant resistance in alfalfa ecosystems.

Shokoohi, Alireza, and William Lamp. Identification of beneficial species (Coleoptera: Carabidae) residing in agricultural drainage ditches. Agricultural drainage ditches are structures typically used to enhance groundwater flow from crop fields and are common on farms along the Eastern Shore of Maryland. These drainage ditches tend to be associated with high plant and arthropod biodiversity relative to adjacent fields, and thus have increasingly been investigated as potential sources of beneficial arthropods. We have previously identified diverse communities of spiders in drainage ditches and shown that certain spider species migrate into soybean fields later in the growing season. This report focuses on ground beetles (Coleoptera: Carabidae), another group of widespread generalist predators that feed on a variety of important insect pests, and their role in agricultural drainage ditch ecosystems. We aim to explore the potential for utilizing existing populations of ground beetles in ditches for biological control in adjacent crops by investigating the following research objectives: (1) to quantify the diversity and abundance of ground beetles in drainage ditches, (2) to investigate the movement of ground beetles between ditches and crop fields throughout the field season to determine the extent to which drainage ditches serve as a source or sink for ground beetles, and 3) to compare the effects of ditch management practices on ground beetle populations including timing of mowing and spreading of straw along ditch banks. Throughout the summer of 2020, we sampled a drainage ditch at the Wye Research and Education Center using foliar sweeps, sticky traps, and pitfall traps, then identified collected ground beetles to genus. During the following fall and spring, we applied treatments to plots along this ditch in a randomized block design, then sampled the ditch again throughout the summer of 2021. Four treatments were chosen consisting of combinations of mowing the ditch vegetation in the fall vs. mowing in the spring and spreading straw across the ditch bank vs. no spreading of straw. We additionally sampled drainage ditches and adjacent crop fields at five other farms during the summer of 2021. We observed a high abundance of ground beetles with an ecologically diverse set of ground beetle genera within sampled ditches. Sampling of drainage ditches at each of the six previously sampled farm will be repeated during the summer of 2022. Directional pitfall traps will also be used along margins between fields and drainage ditches to compare the number of ground beetles traveling in each direction between the habitats throughout the summer growing season.

Hartman, Margaret, and William Lamp. Dragonflies and damselflies (Odonata) as beneficial predators in alfalfa (Medicago sativa). Dragonflies and damselflies are opportunistic predators as adults. However, the potential for adult dragonflies as biological control agents in alfalfa (Medicago sativa) has been understudied. The primary goal of this study is to compare richness and abundance of assemblages of adult species of dragonflies and damselflies among farms and crops. Visual encounter surveys were conducted at three University of Maryland farms during the 2020 and 2021 field seasons. We hope to highlight the importance of adult dragonflies as generalist natural enemies in alfalfa by first determining their richness and abundance in agroecosystems. Odonata provide humans with ecosystem services in several ways, with one primary contribution being their ability to eat large quantities of arthropods often considered pest species. Predatory insects used as biological control in agriculture are an alternative to chemical pesticides and can indirectly improve soil and water quality by reducing chemical inputs into the environment. The primary goal of this study is to compare richness and abundance of assemblages of adult species of dragonflies and damselflies among farms and crops and to use molecular techniques to detect the prey of multiple dragonfly species. Thirty-minute visual encounter surveys (VES) of adult odonates in alfalfa were conducted at three University of Maryland farms in central and western Maryland during the summer 2021 field season. During the VES, the number of novel dragonfly and damselfly encounters were recorded. Crop height, cloud cover, temperature, wind speed, time, behavior at time of sighting and sex were recorded. The behavior of the dragonfly can be described as flying, perching, foraging, aggression or tandem flying. A total of 13 species of odonates were identified in alfalfa during the 2021 summer season. Of these, 11 were Anisoptera and 2 were Zygoptera. The most abundant species in alfalfa between both field seasons were all libellulids and included Tramea lacerata, Libellula luctosa and Plathemis lydia. Dragonfly prey was analyzed by performing next generation sequencing on the fecal material of captive dragonflies post capture in and around alfalfa fields. Dragonflies were captured with an aerial net, placed in a sterile tube for 24 hours, and fecal material was transferred for further DNA purification and amplification. A total of six dragonflies across two University of Maryland farms in central Maryland were captured for fecal DNA analysis. Of these six, two individuals produced readable nucleotide sequences, and these sequences were analyzed using NCBI BLAST. The potential prey of these two dragonflies found in and around alfalfa included families within Hemiptera (Aleyrodidae; Pentatomidae; Aphididae), Diptera (Chloropidae; Sphaeroceridae; Culicidae; Pipunculidae; Drosophilidae; Cecidomyiidae; Canacidae; Syrphidae; Ceratopogonidae), Hymenoptera (Cynipidae; Crabronidae; Braconidae), Lepidoptera (Sesiidae; Nymphalidae), and Coleoptera (Melyridae; Meloidae; Staphylinidae). A majority of the prey detected in their feces were in the order Diptera, but further analyses are needed to determine the relative proportion. This study provides a first examination of the importance of adult dragonflies as generalist predators of agricultural pests. We can begin to inform farmers of the importance of dragonflies as natural enemies, and identify ways to encourage dragonfly communities in agroecosystems to enhance conservation biological control and thus lessen reliance on pesticides.

**Effects of Fertilization Strategy on Triticale Forage Quality and Dairy Cow Performance**

Triticale silage has become a popular forage choice for many dairy producers to increase forage supply. The objectives of this study were to 1) investigate the effect of increasing nitrogen (N) fertility rates with and without sulfur (S) on triticale yield and quality and 2) evaluate production implications when incorporating the forage into dairy cow diets. In Sept 2020, triticale was established at two locations in Maryland. Fertility treatments (defined in Table 1) were applied in March 2021 in a randomized complete block design with four replicates at each location. Plots were mechanically harvested with a forage harvester when forage reached the boot stage in April. Harvested forage was weighed and subsampled for dry matter (DM) yield determination and forage nutritive value analysis. The NLOW, NMED, and NHIGH treatments were also applied to three 2-ha fields to provide triticale for a lactation study which utilized 28 cows in a replicated 4x4 Latin Square design. The standard (ALF) diet contained 60% forage (48% corn silage, 22% alfalfa silage) and 40% concentrate (DM-basis). The LOW, MED, and HIGH diets were formulated by replacing alfalfa silage with NLOW, NMED, or NHIGH triticale silage, respectively, at a rate of 18-20% of diet DM. Both field and feeding studies were analyzed using mixed model analysis, with statistical significance set at *P* ≤ 0.05. Application of N increased forage yield from 3.6 to 5.3 Mg/ha irrespective of application rate or S inclusion (*P* < 0.01). Crude protein (CP) increased linearly with N application rate from 87 to 180 g/kg irrespective of S application (*P* < 0.01). Neutral detergent fiber and net energy did not differ (*P* > 0.05). Feed intake, milk yield, milk fat, and milk protein production averaged 23.3 kg DM/d, 32.8 kg/d, 1.4 kg/d, and 1.0 kg/d, respectively, and were similar for the LOW, MED, and HIGH diets relative to ALF (*P* > 0.05). These results indicate that increasing N application rates can influence forage CP content, and that this forage can be included in the ration without affecting milk production.

|  |  |  |
| --- | --- | --- |
| **Treatment** | **Nitrogen (kg/ha)** | **Sulfur (kg/ha)** |
| CON | 0 | 0 |
| SUL | 0 | 17 |
| NLOW | 56 | 0 |
| NSLOW | 56 | 17 |
| NMED | 112 | 0 |
| NSMED | 112 | 17 |
| NHIGH | 168 | 0 |
| NSHIGH | 168 | 17 |

 **Effects of an Improved Grazing Management System on Dairy Heifer Performance**

As a significant expense on the dairy, producers often look for ways to reduce the cost of the heifer program without reducing performance. The objective of this multi-year study is to evaluate the effect of an improved grazing management system on pregnant dairy heifer performance relative to a conventional system. From April to December 2021, pregnant Holstein heifers (*n*=60) from the University of Maryland Dairy were enrolled in the study twice a month after confirmation of pregnancy and remained on the study until 3 weeks before expected calving. Heifers were blocked by due date and assigned randomly to one of two treatments: rotational grazing (**ROT**) or control (**CON**). Due to rolling enrollment, the size of the treatment groups varied throughout the season (15 to 22 per group) but group size was kept consistent between treatments at any given time. The CON heifers were managed on a 5-acre continuous perennial pasture and received a daily TMR. The ROT heifers were rotationally grazed on 19 acres of perennial and annual pastures sub-divided into 0.6 acre paddocks (1-2 d rotation) and received a daily mineral/corn grain mix at a rate of 0.6 kg/head/d. Body weight (BW), hip height (HH), and body condition score (BCS) were recorded every 14 d. Average daily gain (ADG) was calculated by linear regression and data were analyzed using a mixed model which included the fixed effect of treatment and random effect of block. Mean days on study was 140 and was similar for both treatments. Initial BW (509 kg), BCS (3.7), and HH (145 cm) did not differ between ROT and CON heifers (*P*>0.05). However, ADG (0.63 vs. 0.75 kg/d; *P*=0.03) and final BCS (3.5 vs. 3.7; *P*=0.01) were significantly lower, and final BW (597 vs. 626 kg; *P*=0.08) tended to be lower for ROT heifers. Despite this, ROT heifers were still able to achieve acceptable gains to reach >87% of mature BW before calving. These results demonstrate that bred heifers managed in an improved grazing system can achieve satisfactory growth relative to TMR-fed counterparts. Future work will continue to evaluate the economic implications of this system and investigate potential carry-over effects on first-lactation performance.

5. Impact Statements

During the work on the plant DNA detection from the gut contents of Lycorma delicatula we identified 13 novel host plants that have not been previously reported for L. delicatula on the U.S. territory. The results from this study have important applications for developing effective programs on early monitoring of invasive L. delicatula.

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

6. Published Written Works

Refereed publications

Avanesyan, A., and W.O. Lamp. 2022. Response of five Miscanthus sinensis cultivars to grasshopper

herbivory: implications for monitoring of invasive grasses in protected areas. Plants: Special Issue "Invasive Alien Species in Protected Areas ", 11(1), 53, https://doi.org/10.3390/plants11010053. Invited paper.

McPherson, C., Avanesyan, A., and W.O. Lamp. 2022. Diverse host plants of the first Instars of the invasive Lycorma delicatula: Insights from eDNA metabarcoding. Insects: Special Issue "Advances on Invasive Insect Pests: Insect Behavior, Host Plant Usage, Biocontrol, and More", 13(6), 534,

doi.org/10.3390/insects1306053. Invited paper.

Potts, S., A. Grev, S. Schoenian, and J. Semler. 2021. Gastrointestinal parasite control in cattle: the fecal egg count reduction test. University of Maryland Extension Publication. FS-1175.

Proceedings publication

Bulletins and Extension Factsheets

GenBank Submissions

1. Hartman, M. E., Avanesyan, A. and W.O. Lamp. 2021. Limoniidae sp. isolate MH2h cytochrome c oxidase subunit I (COX1) gene, partial cds; mitochondrial. Direct Submission, GenBank Accession no. OL743186

2. Avanesyan, A. and W.O. Lamp. 2021. Philoscia muscorum voucher ISO-1 cytochrome c oxidase subunit I (COX1) gene, partial cds; mitochondrial. Direct Submission, GenBank Accession no. OK576272

3. McPherson C., Avanesyan, A. and W.O. Lamp. 2021. [Predicted: Carya illinoinensis] isolate 4n ribulose1,5-bisphosphate carboxylase/oxygenase large subunit (rbcL) gene, partial cds; chloroplast. Direct Submission, GenBank Accession no. OK623476

7. Scientific and Outreach Presentations

1. Wilkinson, A., Avanesyan, A., and W.O. Lamp. 2022. Using molecular gut content analysis to characterize PLH (Empoasca fabae) movement within a farmscape. Entomological Society of America Annual Meeting, Eastern Branch. Philadelphia, PA. Poster presentation

2. Shokoohi, A. and W.O. Lamp. 2022. Enhancing biological control by ground beetles (Coleoptera: Carabidae) through agricultural drainage ditch management practices. Entomological Society of America Eastern Branch Annual Meeting, Philadelphia, PA. Oral presentation

3. Grev, A.M., S.B. Potts, J.W. Semler. 2022. Effect of an improved grazing management system on dairy heifer performance. In Proceedings: American Forage and Grassland Council 2022 Annual Meeting, Kansas City, MO.

 Grev, A.M., S.G. Schoenian, J.W. Semler, and D.J. O’Brien. 2022. Effects of whole-grain supplementation on health, growth, and profitability of pasture-raised lamb. In Proceedings: American Forage and Grassland Council 2022 Annual Meeting, Kansas City, MO.

Grev, A., S. Schoenian, J. Semler, and D. O'Brien. 2021. Effect of energy supplementation on growth, health, and carcass traits of pasture-raised lambs. Journal of Animal Science. 99(Suppl. 3): 199-200.

Potts, S.B., A.M. Grev, J.W. Semler, S. Schoenian, and D. O'Brien. 2021. Assessment of the presence of anthelmintic resistance in Maryland beef cattle herds. Journal of Animal Science. 99(Suppl. 3): 325

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

8. Collaborative Grants

Course proposal: Application of a DNA barcoding module to BSCI 467, Freshwater Biology: Addressing the loss of species and genetic diversity (PIs: Drs. Bill Lamp, Alina Avanesyan, and David Hawthorne, Department of Entomology). $20,000. Submitted on 06/09/2022.

Graduate Student Research Grant. Northeast Sustainable Agriculture Research and Education. 2021. Dragonflies as potential biological control on farms: Prey assessment using a DNA approach (PIs: Margaret Hartman and William Lamp). $15,000.

Potts, S., A. Grev, S. Schoenian, J. Semler, M. Perdue, C. Sasscer, E. Crowl, and D. O’Brien. 2022-2024. Implementation of Improved Intestinal Parasite Management Practices on Maryland Livestock Farms. Northeast SARE Research & Education Program. Co-PI. Funding of $165,354 to education livestock producers on best management practices for internal parasite management.

Lamp, W. and A. Grev. 2021-2026. Fostering Resilience and Ecosystem Services in Landscapes by Integrating Diverse Perennial Circular Systems. USDA NIFA AFRI SAS Grant. Co-PI. Funding of $603,542 to support forage systems research, teaching, and Extension programming in Maryland.

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

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

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

9. Graduate students

Darsy Smith, PhD student

Expected graduation date: May 2024

Dissertation title: Response of pea aphid and ladybeetles to host plant resistance in alfalfa ecosystems.

Hartman, Margaret, Master’s degree

Expected graduation: December 2022.

Thesis title: Community composition and diet analysis of dragonflies and damselflies (Order Odonata) associated with agroecosystems.

Shokoohi, Alireza, Master’s degree

Expected greaduation: May, 2023.

Thesis title: Enhancing biological control by ground beetles (Coleoptera: Carabidae) through agricultural drainage ditch management practices.

**Utah**

1. Impact Nugget

2. New Facilities and Equipment

3. Unique Project Related Findings

4. Accomplishment Summaries

*Employing Forage Legumes to Improve the Sustainability of Ruminant Production*, J. MacAdam

A study carried out under irrigation compared the forage production and nutritive value as well as the intake and enteric methane emissions of dry cows, pregnant cows, yearling calves, and 2-year-old heifers on irrigated pastures. The treatments included two non-bloating monoculture legume (birdsfoot trefoil and cicer milkvetch) pastures and a monoculture meadow bromegrass pasture. A total mixed ration treatment was included in the final two years of the study. This project demonstrated that enteric methane as a function of intake was significantly (40%) less on monoculture legume pastures than on monoculture meadow bromegrass pasture for all the tested classes of cattle. It also demonstrated that methane emissions did not differ when 2-year-old heifers grazed legume pastures or were fed a total mixed ration in confinement.

A dryland study of six sainfoin cultivars was planted in the early autumn of 2018 and sampled at the 10, 50, and 100% bloom stage for two years, in 2019 and 2020, and at the 100% bloom and one month post-bloom stage for two years, in 2021 and 2022. The yield of these cultivars was greatest in the first year after planting, ranging between 5.29 (Shoshone) and 7.63 (Remont) Mg/ha, and decreasing to between 2.21 (Delaney) and 4.30 (Shoshone) Mg/ha by the third year after planting. Forage quality did not decrease significantly over the four years of the study, or as sainfoin matured from 10 to 100% bloom; blooms mature quickly and stems were fully elongated when flowering began. Tannin concentration was similar for all cultivars and in the range of 4% of dry matter although it varied with precipitation. At one month after full bloom, seed pods were maturing and protein concentration of sainfoin had decreased from 18.60% at full bloom to 8.95%. However, energy concentration measured as non-fiber carbohydrate concentration was still high: 47% at full bloom and 40% at one month post-bloom. Digestibility decreased from 82% at full bloom to 69% at one month post-bloom, and total digestible nutrients (TDN) decreased from 71% at full bloom to 57% at one month post-bloom.

5. Impact Statements

Most irrigated pastures in the northern Mountain West are dominated by grasses, and the series of studies carried out on grass and legume pastures with different classes of beef cattle demonstrated that cattle enteric methane emissions can be greatly reduced by substituting non-bloating legumes for grasses in irrigated pastures.

The results of the 4-year-long dryland sainfoin study demonstrated that sainfoin is a high-protein and extremely high-energy forage at maturity, and that it retains nutritive value with maturation even under dryland conditions.

6. Published Written Works

*Refereed publications*

Lagrange, S., J. MacAdam, B. Stegelmeier, and J. Villalba. 2021. Grazing diverse combinations of tanniferous and non-tanniferous legumes: Implications for foraging behavior, performance and hair cortisol in beef cattle. Journal of Animal Science, 99:1-11.

Lagrange, S., J. MacAdam, and J. Villalba. 2021. The use of tannin containing forage legumes to improve sustainability in forage-livestock production. Agronomy, 11, 2264

Leggett, K., R. McCann, M. Brunson, B.A. Miller, and J. MacAdam. 2021. “From a chef’s perspective or what I can sell on the menu?” Exploring culinary professionals’ attitudes toward specialty beef production and barriers to adoption. Agroecology and Sustainable Food Systems,45:246-266.

Li, D., G. Shu, H. Wang, Y. Xu, J. Adni, Y. Zhang, J.W. MacAdam, J.J. Villalba, X. Dai and L. Chen\*. 2021. *In vitro* fermentation performance of alfalfa (*Medicago sativa* L.) mixed with different proportions of paper mulberry (*Broussonetia* *papyrifera*) leaves (PML) or condensed tannins extracted from PML. Italian Journal of Animal Science 20: 1740-1748.

Spackman, C.N., C.A. Stonecipher, K.E. Panter, and J.J. Villalba. 2021 Grazing rotation on restored rangeland as a new tool for medusahead control. Western North American Natrualist 81: 438-442.

Spackman, C. N., C.A. Stonecipher, and J.J. Villalba. 2021. Fermentation kinetics of medusahead (*Taeniatherum caput-medusae*) treated with different glyphosate rates at different particle size. Journal of Animal Science and Technology. In Press.

Stonecipher, C.A., C.N. Spackman, K.E. Panter, and J.J. Villalba.2021. The use of a herbicide as a tool to increase livestock consumption of medusahead (*Taeniatherum caput-medusae*). Invasive Plant Science and Management. 2021:1-9.

Villalba\*, J.J., S. Ates, and J.W. MacAdam. 2021 Non-fiber carbohydrates in forages and their influence on beef production systems. *Frontiers in Sustainable Food Systems* 5:566338.

*Proceedings publication*

DiLorenzo, N., J.C.B. Dubeux Jr., L. Garcia, R.D. Guevara, S. Lagrange, J. MacAdam, and J.J. Villalba. 2021. Legumes as a strategy for reducing greenhouse gas emissions of forage-livestock systems. Proceedings, Joint XXIV International Grassland Congress and XI International Rangeland Congress, 23-29 October 2021, Nairobi, Kenya.

7. Scientific and Outreach Presentations

 *Abstracts , symposium and conference presentations*

MacAdam, J.W. 2021. Effect of oven- vs. freeze-drying on the condensed tannin concentrations of sainfoin and birdsfoot trefoil. *In* Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.

8. Collaborative Grants

NIFA Sustainable Agriculture Systems CAP Grant, Using Smart Foodscapes to Enhance the Sustainability of Western Rangelands. 10/01/21 to 09/30/26. Villalba PI; MacAdam Co-PI; $6,800,000.

Utah State University AES Seed Grant Program. Using Smart Foodscapes to Transform Cowherd Nutrition on Western Rangeland. 07/01/21 to 06/30/23. Villalba PI, MacAdam Co-PI; $79,886.

**Kentucky**

1. Impact Nugget

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

2. New Facilities and Equipment

The USDA-ARS-FAPRU group has received Federal money for a new building on the UK campus, which will house some of the UK forage group and other UK faculty. A location on the UK campus in Lexington has been identified, and site planning and building design processes have begun. The design process is scheduled to be completed this year (2022), with site prep and building work commencing Spring 2023. The building is currently anticipated to open in Spring 2026.

The forage program has received a new GasMet FTIR for soil-to-atmosphere greenhouse gas measurements and new Ankom Fiber Digestors and cyclone mills to support our collaborative work with the USDA-ARS-FAPRU group.

Unfortunately, the new Grain & Forage Center for Excellence, which houses one UK forage faculty member, was completely destroyed by a tornado in December 2021. That faculty member led the field clean-up process in early 2022 and is doing his best to maintain his research and extension commitments for 2022; however, without power or basic facilities, maintenance is challenging. Temporary offices are slated to be available Fall 2022 and some barns are being re-built. PI's are purchasing replacement equipment, vehicles, lab supplies, etc. with insurance funding. The building will be re-built, but it will take years.

3. Unique Project Related Findings

Plant damage by invertebrate herbivores and pathogens influences the dynamics of grassland ecosystems, but anthropogenic changes in nitrogen and phosphorus availability can modify these relationships. Using a globally distributed experiment, we describe leaf damage on 153 plant taxa from 27 grasslands worldwide, under ambient conditions and with experimentally elevated nitrogen and phosphorus. Invertebrate damage significantly increased with nitrogen addition, especially in grasses and non- leguminous forbs. Pathogen damage increased with nitrogen in grasses and legumes but not forbs. Effects of phosphorus were generally weaker. Damage was higher in grasslands with more precipitation, but climatic conditions did not change effects of nutrients on leaf damage. On average, invertebrate damage was relatively higher on legumes and pathogen damage was relatively higher on grasses. Community-weighted mean damage reflected these functional group patterns, with no effects of N on community-weighted pathogen damage (due to opposing responses of grasses and forbs) but stronger effects of N on community- weighted invertebrate damage (due to consistent responses of grasses and forbs). As human-induced inputs of nitrogen and phosphorus continue to increase, understanding their impacts on invertebrate and pathogen damage becomes increasingly important. Our results demonstrate that eutrophication frequently increases plant damage and that damage increases with precipitation across a wide array of grasslands. Invertebrate and pathogen damage in grasslands is likely to increase in the future, with potential consequences for plant, invertebrate and pathogen communities, as well as the transfer of energy and nutrients across trophic levels.

4. Accomplishment Summaries

During 2021, faculty from University of Kentucky published data from a number of forage and alfalfa variety trials, other on-farm work, and scientific studies and trained numerous undergraduate and graduate students. Outreach activities were still impacted by the COVID-19 pandemic, though some traditional activities came back in a reduced capacity or altered fashion (e.g., farm visits, interactions with producer and commodity groups, virtual scientific meetings, in-person teaching, etc.). We collected data evaluating the effects of different levels of symbiotic diversity on soil and forage parameters, and we continued work in collaboration with USDA-ARS-FAPRU evaluating the effects of biochanin A (an isoflavone produced by red clover) supplementation on ruminant N use efficiency and N excreta to the environment, as well as excreta effects on greenhouse gas emissions from soils. In addition, we initiated the crop rotation - hemp AFRI project and are advising a PhD student and postdoc working on that project.

5. Impact Statements

***"Patch burning tall fescue invaded grasslands alters alkaloids and tiller defoliation with implications for cattle toxicosis" - Scasta et al. 2021. Rangeland Ecology & Management.***

*Issue:* Tall fescue (*Schedonurus arundinaceus*), an exotic invasive grass in North America, can associate with a fungal endophyte that causes livestock toxicity. Native prairies are frequently managed with interactive fire and grazing, yet little is known regarding tall fescue's endophytic and toxicological responses to these management practices.

*Action:* From 2012 to 2014, we applied patch-burn grazing (PBG - burning a different third annually) or graze and burn (GAB - burning completely in 2012 but no fire in 2013 or 2014) treatments to tall fescue-invaded grasslands. Burning happened in March/April, and cattle grazing occurred during the growing season. Tall fescue tillers were analyzed for *Epichloë* endophyte presence and alkaloid concentrations. Cattle toxicosis was assessed via fecal ergovaline levels. In GAB, tiller defoliation was no different the year of the burn than the years without fire. In PBG, burnt patches had increased tall fescue tiller defoliation compared to unburned patches. Cattle did not discriminate between endophyte-infected and endophyte-free tillers in either treatment. Endophyte infection levels were inversely related to years since fire (YSF), and various alkaloids displayed asynchronous responses to YSF. Cattle had no detectable fecal ergovaline when managed with patchy or complete pasture fires.

*Impact:* Patchy fires can be used to facilitate cattle defoliation of tall fescue tillers within fescue-invaded native prairies. Patch burning tall fescue-invaded grasslands alters alkaloids and tiller defoliation with implications for cattle toxicosis. Future research should incorporate greater intra-annual resolution of plant phenology relative to focal grazing, fire, and alkaloid expression.

***"Negative effects of nitrogen override positive effects of phosphorus on grassland legumes worldwide" - Tognetti et al. 2021. PNAS.***

*Issue:* Predicting the effects of anthropogenic nutrient enrichment on plant communities is critical for managing implications for biodiversity and ecosystem services. Plant functional types that fix atmospheric nitrogen (e.g., legumes) may be at particular risk of nutrient-driven global decline, yet global-scale evidence is lacking.

*Action:* Using an experiment in 45 grasslands across six continents, we showed that legume cover, richness, and biomass declined substantially with nitrogen additions. Although legumes benefited from phosphorus, potassium, and other nutrients, these nutrients did not ameliorate nitrogen-induced legume decline.

*Impact:* Given global trends in anthropogenic nutrient enrichment, our results indicate the potential for global decline in grassland legumes, with likely consequences for biodiversity, food webs, soil health, and genetic improvement of protein-rich plant species for food production.

6. Published Written Works

***Refereed publications***

Langley, J.A., E. Grman, K.R. Wilcox, M.L. Avolio, K.J. Komatsu, S.L. Collins, S.E. Koerner, M.D. Smith, A.H. Baldwin, W. Bowman, N. Chiariello, A. Eskelinen, H. Harmens, M. Hovenden, K. Klanderud, ***R.L. McCulley***, V.G. Onipchenko, C.H. Robinson, and K.N. Suding. **2021**. Do tradeoffs govern plant species responses to different global change treatments? Ecology 103(6):e3626. doi: 10.1002/ecy.3626

Arnillas, C.A., E.T. Borer, E.W. Seabloom, J. Alberti, S. Baez, J.D. Bakker, E.H. Boughton, Y.M. Buckley, M.N. Bugalho, I. Donohue, J. Dwyer, J. Firn, R. Gridzak, N. Hagenah, Y. Hautier, A. Helm, A. Jentsch, J.M.H. Knops, K.J. Komatsu, L. Laanisto, R. Laungani, ***R.L. McCulley***, J.L. Moore, J.W. Morgan, P. Luis Peri, S.A. Power, J. Price, M. Sankaran, B. Schamp, K. Speziale, R. Standish, R. Virtanen, and M.W. Cadotte. **2021**. Opposing community assembly patterns for dominant and nondominant plant species in herbaceous ecosystems globally. Ecology and Evolution 11(24):17744-17761. doi: 10.1002/ece3.8266

Ebeling, A., A.T. Strauss, P.B. Adler, C.A. Arnillas, I.C. Barrio, L.A. Biederman, E.T. Borer, M.N. Bugalho, M.C. Caldeira, M.W. Cadotte, P. Daleo, N. Eisenhauer, A. Eskelinen, P.A. Fay, J. Firn, P. Graff, N. Hagenah, S. Haider, K.J. Komatsu, ***R.L. McCulley***, C.E. Mitchell, J.L. Moore, J. Pascual, P.L. Peri, S.A. Power, S.M. Prober, A.C. Risch, C. Roscher, M. Sankaran, E.W. Seabloom, H. Schielzeth, M. Schutz, K.L. Speziale, M. Tedder, R. Virtanen, and D.M. Blumenthal. **2021**. Nutrient enrichment increases invertebrate herbivory and pathogen damage in grasslands. Journal of Ecology 110(2):327-339. doi: 10.1111/1365-2745.13801

Wilfahrt, P.A., A.L. Asmus, E.W. Seabloom, J.A. Henning, P. Adler, C.A. Arnillas, J.D. Bakker, L. Biederman, L.A. Brudvig, M. Cadotte, P. Daleo, A. Eskelinen, J. Firn, W.S. Harpole, Y. Hautier, K.P. Kirkman, K.J. Komatsu, R. Laungani, A. MacDougall, ***R.L. McCulley****,* J.L. Moore, J.W. Morgan, B. Mortensen, R. Ochoa-Hueso, T. Ohlert, S.A. Power, J. Price, A.C. Risch, M. Schuetz, L. Shoemaker, C. Stevens, A.T. Strauss, P.M. Tognetti, R. Virtanen, and E.T. Borer. **2021**. Temporal rarity is a better predictor of local extinction risk than spatial rarity. Ecology 102(11):e03504. doi: 10.1002/ecy.3504

Jing, X., C.M. Prager, E.T. Borer, N.J. Gotelli, D.S. Gruner, J-S. He, K. Kirkman, A.S. MacDougall, ***R.L. McCulley***, S.M. Prober, E.W. Seabloom, C.J. Stevens, A.T. Classen, and N.J. Sanders. **2021**. Spatial turnover of multiple ecosystem functions is more associated with plant than soil microbial B-diversity. Ecosphere 12(7): e03644. Doi: 10.1002/ecs2.3644

Tognetti, P.M., S.M. Prober, S. Baez, E.J. Chaneton, J. Firn, A.C. Risch, M. Schuetz, A.K. Simonsen, L. Yahdjian, E.T. Borer, E.W. Seabloom, C.A. Arnillas, J.D. Bakker, C.S. Brown, M.W. Cadotte, M.C. Caldeira, P. Daleo, J.M. Dwyer, P.A. Fay, L.A. Gherardi, N. Hagenah, Y. Hautier, K.J. Komatsu, ***R.L. McCulley***, J.N. Price, R.J. Standish, C.J. Stevens, P.D. Wragg, and M. Sankaran. **2021**. Negative effects of nitrogen override positive effects of phosphorus on grassland legumes worldwide. PNAS 118(28): e2023718118. Doi: 10.1073/pnas.2023718118

Avolio, M.L., K.J. Komatsu, S.L. Collins, E. Grman, S.E. Koerner, A.T. Tredennick, K.R. Wilcox, S. Baer, E.H. Boughton, A.J. Britton, B. Foster, L. Gough, M. Hovenden, F. Isbell, A. Jentsch, D.S. Johnson, A.K. Knapp, J. Kreyling, J.A. Langley, C. Lortie, ***R.L. McCulley***, J.R. McLaren, P.B. Reich, E.W. Seabloom, M.D. Smith, K.N. Suding, K.B. Suttle, and P.M. Tognetti. **2021**. Determinants of community compositional change are equally affected by global change. Ecology Letters 24(9):1892-1904. Doi: 10.1111/ele.13824

Scasta, J.D., ***R.L. McCulley***, D.M. Engle, and D. Debinski. **2021**. Patch burning tall fescue invaded grasslands alters alkaloids and tiller defoliation with implications for cattle toxicosis. Rangeland Ecology & Management 75:130-140.

***Proceedings publications***

None to report.

***Extension Publications***

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

Henning, J., R. Smith, and C. Teutsch. **2021**. Baling Forage Crops for Silage. AGR-173.

Henning, J., R. Smith, C. Teutsch, and K. VanValin. **2021**. Utilizing Drought Stressed Soybeans for Forage. AGR-262.

Arnold, M. S. Bogle, B. Coleman, R. Smith, and K. Wise. **2021**. Blackpatch of Forage Legumes: Casues of Slaframine Toxicosis or 'Slobbers' in Animals. ID-230.

Anderson, L., M. Arnold, D. Bullock, K. Burdine, R. Burris, B. Crites, J. Henning, S. Higgins, S. Isaacs, K. Laurent, J. Lehmkuhler, L. Moser, G. Rentfrow, K. Schmidt, R. Smith, C. Teutsch, L. Townsend, K. VanValin, and P. Vijayakumar. **2021**. The Kentucky Beef Book, 2021. ID-108.

Henning, J., K. Lea, R. Smith, and C. Teutsch.  **2021**. Improving Kentucky Small Ruminant Pastures. AGR-264.

Henning, J., G. Lacefield, R. Smith, and C. Teutsch. **2021**. Growing Lespedeza in Kentucky for Cattle, Sheep and Goats. AGR-86.

Henning, J. R. Smith, and C. Teutsch. **2021**. Bermudagrass: A Summer Forage in Kentucky. AGR-48.

Henning, J., T. Keene, R. Smith, and C. Teutsch. **2021**. Crabgrass. AGR-232.

Henning, J., T. Phillips, R. Smith, and C. Teutsch. **2021**. Growing Wheat for Forage. AGR-263.

Hayes, M. and C. Teutsch. **2021**. Using Electric Offsets as Part of Fencing Systems. ID-269.

Henning, J., J. McGrath, E. Ritchey, R. Smith, and C. Teutsch. **2021**. Soil Sampling and Nutrient Management in Small Ruminant Pastures. AGR-265.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2021**. 2021 Timothy and Kentucky Bluegrass Report. PR-803.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2021**. 2021 Long-Term Summary of Kentucky Forage Variety Trials. PR-810.

Bruening, B., J. Henning, G. Olson, R. Smith, and C. Teutsch. **2021**. 2021 Annual Grass Report: Warm Season and Cool Season (Cereals). PR-809.

Costa, J. Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2021**. 2021 Cool-Season Grass Grazing Tolerance Report. PR-807.

Henning, J., L. Lawrence, G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2021**. 2021 Cool-Season Grass Horse Grazing Tolerance Report. PR-808.

Costa, J., Henning, J., G. Olson, R. Smith, and C. Teutsch. **2021**. Alfalfa Grazing Tolerance Report. PR-805.

Costa, J., Henning, J., G. Olson, R. Smith, and C. Teutsch. **2021**. 2021 Red and White Clover Grazing Tolerance Report. PR-806.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2021**. 2021 Orchardgrass Report. PR-801.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2021**. 2021 Annual and Perennial Ryegrass and Festulolium Report. PR-804.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2021**. 2021 Alfalfa Report. PR-799.

Henning, J., G. Olson, R. Smith, and C. Teutsch. **2021**. 2021 Red and White Clover Report. PR-800.

Henning, J., G. Olson, T. Phillips, R. Smith, and C. Teutsch. **2021**. 2021 Tall Fescue, Bromegrass, and Meadow Fescue Report. PR-802.

7. Scientific and Outreach Presentations

 McBride, S.G., E.M. Levi, J.A. Nelson, S.R. Archer, P.W. Barnes, H.L. Throop, and R.L. McCulley. **2021**. Drivers of dryland decomposition depend on whether litter is covered by soil. Ecological Society of America Annual Meeting, virtual.

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***. 2017-2023. **$500,000**

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

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

9. Graduate students

**William Fleming**, MS in Integrated Plant & Soil Sciences, expected graduation **2024**, title - TBD.

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

**Jordyn Bush**, MS in Integrated Plant & Soil Sciences, expected graduation **2022**, title - TBD.

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

**Alayna Jacobs**, PhD in Integrated Plant & Soil Sciences, expected graduation **2022**, "Manipulating species diversity: environmental impacts in row crop, livestock, and grassland agroecosystems."

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

**Tennessee**

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

2. New Facilities and Equipment

* N/A

3. Unique Project Related Findings

* N/A

4. Accomplishment Summaries

Economic outcomes for transitioning to organic forage production: Research on the use of forages to transition cropland to organic production is limited. Our objective was to determine the cost of transitioning from conventional to organic production using perennial and annual forage systems. The study was conducted at the Middle Tennessee AgResearch and Education Center, in Spring Hill, TN. Five forage treatments were compared: tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.] monoculture, bermudagrass [*Cynodon dactlyon* (L.) Pers.] monoculture, tall fescue and alfalfa (*Medicago sativa* L.) mixture, bermudagrass and alfalfa mixture, and an annual rotation of a cool-season mixture, including winter wheat (*Triticum aestivum* L.) and winter pea (*Pisum sativum* L.) and a warm-season mixture of sorghum-sudangrass [*Sorghum bicolor* (L.) Moench x *Sorghum sudanese* (Piper) Stapf] and cowpea [*Vigna unguiculata* (L.) Walp.]. Perennial forages were established in 2017 and 2018 following orchard removal and a fallow period. Regular production measurements began in 2019 when the plots achieved full organic certification status. Tall fescue had the lowest cost for the overall transition period. However, on a cost per unit of DM (dry matter) forage mass and on a cost per unit of crude protein (CP) basis, all treatments were similar, with a range between $0.02 and $0.03 lb-1 for DM forage mass and between $0.15 to $0.20 lb-1 for CP, except for the more costly bermudagrass monoculture that was $0.06 lb-1 DM forage mass and $0.40 lb-1 CP. Given the lack of a premium during the transition period, tall fescue was the most cost-effective transition forage.

Corn production in living mulch systems in the Southeastern U.S.: The living mulch (LM) system is a novelty in the southeastern U.S. and the ability to graze the LM after corn production can increase the land use efficiency. The objective of this study was to evaluate the benefits of LM in corn silage and grain production, and to evaluate the potential of LM grazing between the corn growing season. The experiment was conducted in Spring Hill, TN in 2020 and 2021, and consisted of two LM species, WC (*Trifolium repens* L. [WC]) and a mixture of crimson clover (*Trifolium incarnatum* L.) and cereal rye (*Secale cereale* L. [CCCR]). Cull cows were used for the grazing period of four weeks before planting and after harvest of corn. The study evaluated the botanical composition (BC), LM mass (LMM), nutritive value (NV), corn silage and grain production, and cows average daily gain (ADG). The WC treatment had a greater weed control than CCCR. In 2020, when differences in LMM were observed, CCCR had greater LMM than WC. Meanwhile, in 2021 the LMM did not differ between WC and CCCR, with both treatments showing less mass in spring and early summer. Greater silage and grain production was observed in 2020 for WC paddocks, but in 2021 no LM differences were observed. The ADG was greater in WC than CCCR paddocks. It was concluded that WC as LM can lead to greater corn production than CCCR. The LM for grazing is a beneficial strategy if feeding costs are greater than $2.28 head/day.

Nitrogen requirements for corn production in white clover living mulch systems.

Fertilization rates must be assessed when adding a legume living mulch (LM) in corn (*Zea mays* L.) silage or grain production. The objective of this study was to determine the optimum amount of N fertilization in white clover (*Trifolium repens* L. [WC]) LM in grain and silage production. The study was conducted in Spring Hill, TN from Mar 2020 to Sept 2021. The treatments were [C-0] no LM + no N, [C-135] no LM + 135 kg ha-1 N, [CLM-0] LM + no N, [CLM-45] LM + 45 kg ha-1 N, [CLM-90] LM + 90 kg ha-1 N, [CLM-135] LM + 135 kg ha-1 N, all treatments had corn silage or grain hybrids seeded in the first week of June. It was assessed the production of corn at harvest, botanical composition, and LM mass throughout the corn growing season. The results showed that the lack of precipitation after seeding affected corn development, especially due to the interspecies competition between LM and corn. The weed suppression by WC was greater in the second year after establishment, therefore, it is important to suppress WC growth to decrease its competition with corn. The N rate did not affect the nutritive value of the LM, from May to Sept the CP decreased, and fiber content increased, likely due to maturity and species composition. In conclusion, although adding WC did not lead to similar corn productivity as in conventional systems, adding LM to the field can aid in weed control and corn nutritive value.

5. Impact Statements

6. Published Written Works

*Refereed publications*

1. Quinby, M\*.**, R.L.G. Nave**, Sykes, V. R., Bates, G. E., and M. Levi and N. Hill. 2022. Corn production in living mulch systems in the Southeastern U.S. Agron. J. (in review).
2. Keyser, P., A. Ashworth, C. Gelley, **R.L.G. Nave**,and J. Rhinehart. 2022. Evaluation of five C4 forages in the tall fescue belt. Agron. J. (in review).
3. Quinby, M\*.**, R.L.G. Nave**, Sykes, V. R., Bates, G. E., and C. Sams. 2022. Nitrogen requirements for corn production in white clover living mulch systems. Grassland Sci. (in review).
4. Kubesch, J.O.C.\*, **R.L.G. Nave**,A.P. Griffith, S. Cui, G.E. Bates. 2022. Economic outcomes of cool and warm-season swards in transitioning organic swards. Crop Forage and Turfgrass Management. doi.org/10.1002/csc2.20461
5. Kubesch, J.O.C.\*, **R.L.G. Nave**,S. Cui, G.E. Bates, D.M. Butler, and V. R. Pantalone. 2022. Transitional organic forage systems in the U.S. Southeast: production and nutritive value. Agron. J. doi.org/10.1002/agj2.21001
6. Xiong, Y.V.\*, R.L.G. Nave, A.P. Griffith, M.P. Quinby, G.E. Bates, and M.D. Corbin. 2021. Emergency seeding of cool-season annuals into perennial grass after fall drought. Crop Forage and Turfgrass Management. Crop Forage and Turfgrass Management. doi.org/10.1002/cft2.20018.
7. Quinby, M.P.\*, **R.L.G. Nave**,R.M. Sulc, M. Castillo, L. Schneider, G.E. Bates, and D. McIntosh. 2021. Comparison of alfalfa mixed with tall fescue and bermudagrass on forage accumulation, botanical composition, and nutritive value. Crop Sci. doi:10.1002/csc2.20461
8. Tilhou, N.W.\*, **R.L.G. Nave,** S. Jagadamma, N. Eash, and J.T. Mulliniks. 2021. Forage species and summer management impacts on soil labile carbon and nitrogen in winter stockpiled grazing systems. Agrosystems, Geoscience and Environment.. doi:10.1002/agg2.20132

*Proceedings publications*

None

*Book chapters*

**Nave,** **R.L.G.** and J. Tucker. 2022. Forage and Roughage Utilization/Grazing and Pasture Management. In: Modern Beef Production: Integrative approaches with nutrition, reproduction, and genetics. (in review)

7. Scientific and Outreach Presentations

 *Abstracts , symposium and conference presentations*

1. Quinby, M.P., and **R.L.G. Nave**. 2021. Corn in living mulch systems: Grazing potential. International Annual Meetings ASA-CSSA-SSSA – Salt Lake City/UT.
2. Corbin, M.D., **R.L.G. Nave**. 2021. Legumes vs. conventional nitrogen fertilization methods for stockpiling tall fescue. International Annual Meetings ASA-CSSA-SSSA – Salt Lake City/UT.
3. Xiong, Y., and **R.L.G. Nave**. 2021. Restoring cool-season pastures with alfalfa and crabgrass to increase forage mass in the Southeast. International Annual Meetings ASA-CSSA-SSSA – Salt Lake City/UT.

8. Collaborative Grants

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| 1. Hill, N. S., M. Levi, R. Noland, **R.L.G. Nave**, S. Jagadamma, A. Rius. Demonstrating the soil health benefits of the white clover living mulch production system among different soil classes and geographical landscapes. USDA-NRCS-Conservation and Innovation Grant. Oct. 2018 – Sep. 2022. ($641,749) |
| 2. **Nave, R.L.G.**, J.J. Tucker, G.E. Bates and A. Griffith. Restoring grasslands with the addition of alfalfa in an effort to sustainably increase alfalfa production in the Southeast. USDA-NIFA-Alfalfa Seed and Alfalfa Forage System Program. Sep 2019-Oct 2022. ($499,194) |
| 3. Sykes, V., and **Nave, R.L.G.** 2021. Living mulch in organic corn systems. Tennessee Corn Promotion Board. Jan 2021 – Jan 2023. ($30,000) |
| 4. Picasso, V., Berti, M., Cassida, K., Guretzky, J., …, **Nave, R.L.G**., Sykes, V., et al. 2021. Fostering resilience and ecosystem services in landscapes by integrating diverse perennial circular systems. USDA/AFRI/SAS. Oct 2021 – Sep 2026. ($10,000,000) |
| 5. **Nave, R.L.G.**, Sykes, V., Boyer, C., Yin, F., and Kelly, H. 2022. Optimizing organic corn production under different living mulch systems. USDA-NIFA-Organic Transitions Program. ($699,360). Sep 2022 – Sep 2025. |

9. Graduate students

M.P. Quinby. PhD. Graduation date: July 2022. Corn grain and silage production under the white clover living mulch system.

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

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

Y. Roberts, M.S. Expected graduation date: Fall 2024. Alfalfa and corn intercropping systems in the Southeastern U.S.

**Texas**

1. **Impact Nugget**

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

1. **New Facilities and Equipment**

Nothing to report.

1. **Unique Project Related Findings**

Texas A&M AgriLife Research evaluated the nutritive value as impacted by management of forage sorghum and small grains, evaluated the potential for Teff, *Brachiaria*, or summer-dormant cool-season grasses to be incorporated into Texas forage systems. Determined the potential of warm-season legume dual crops to secure soil and the impact on water footprint, determined the feasibility and effectiveness of incorporating co-products, such as distillers grains and lipid-extracted algae into agriculture systems, released native grass, legume and other herbaceous forb cultivars, and disseminated results to land owners.

1. **Accomplishment Summaries**

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

1. **Impact Statements**

Issue: 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. Forage cropping systems using DSSAT crop models for simulation of double-cropping cowpeas and wheat for the southern United States is the first such model that illustrates climatic conditions with soil types and fertilization regimens.

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

Action: Forage quality research led to the first published model that predicts forage nutritive value of bermudagrass pastures on a dynamic, daily basis. (Woli et al. 2021). Another ‘first-model’ includes modifications of TDN (total digestible nutrients) for bermudagrass and other warm-season perennial grasses (Woli et al. 2020). This will have direct application for commercial forage laboratory analyses.

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

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

Contact:

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Cooperators: Muir, Olson, Redmon, and Rouquette

1. **Published Written Works**

*Book/Journal Issue*

Nothing to report.

*Book Chapters*

Nothing to report.

*Refereed Journal Articles*

Bagnall, D.K., C.L.S. Morgan, G.M. Bean, D. Liptzin, S.B. Cappellazzi, M. Cope, K.L.H. Greub, C.E. Norris, E.L. Rieke, P.W. Tracy, E. Aberle, A. Ashworth, O. Bañuelos Tavarez, A.I. Bary, R.L. Baumhardt, A. Borbón Gracia, D.C. Brainard, J.R. Brennan, D. Briones Reyes, D. Bruhjell, C.N. Carlyle, J.J.W. Crawford, C.F. Creech, S.W. Culman, B. Deen, C.J. Dell, J.D. Derner, T.F. Ducey, S.W. Duiker, M.F. Dyck, B.H. Ellert, M.H. Entz, A. Espinosa Solorio, S.J. Fonte, S. Fonteyne, A.-M. Fortuna, **J.L. Foster**, A.J. Franzluebbers, L.M. Fultz, A.V. Gamble, C.M. Geddes, D. Griffin-LaHue, J.H. Grove, S.K. Hamilton, X. Hao, Z.D. Hayden, J.L. Heitman, N. Honsdorf, J.A. Howe, J.A. Ippolito, G.A. Johnson, M.A. Kautz, N.R. Kitchen, S. Kumar, K.S.M. Kurtz, F.J. Larney, K.L. Lewis, A.B. Leytem, M.A. Liebig, M. Liebman, A. Lopez Ramirez, S. Machado, B. Maharjan, M.A. Martinez Gamiño, W.E. May, M.P. McClaran, M.D. McDaniel, N. Millar, J.P. Mitchell, A.D. Moore, P.A. Moore Jr., M.M. Gutiérrez, K.A. Nelson, E.C. Omondi, S.L. Osborne, D.L. Osmond, L. Osorio Alcalá, P. Owens, E.M. Pena-Yewtukhiw, H.J. Poffenbarger, B. Ponce Lira, J.R. Reeve, T.M. Reinbott, M.S. Reiter, E.L. Ritchey, K.L. Roozeboom, Y. Rui, A. Sadeghpour, U.M. Sainju, G.R. Sanford, W.F. Schillinger, R.R. Schindelbeck, M.E. Schipanski, A.J. Schlegel, K.M. Scow, L.A. Sherrod, A.L. Shober, S.S. Sidhu, E. Solís Moya, M. St. Luce, J.S. Strock, A.E. Suyker, V.R. Sykes, H. Tao, M.L. Thompson, A. Trujillo Campos, L.L. Van Eerd, N. Verhulst, T.J. Vyn, Y. Wang, D.B. Watts, B.B. William, D.L. Wright, T. Zhang, and C.W. Honeycutt. 2021. Selecting soil hydraulic properties as indicators of soil health: Measurement response to management and site characteristics. Soil Sci. Soc. Am. J. (In Press)

Bagnall, D.K., C.L.S. Morgan, M. Cope, G.M. Bean, S.B. Cappellazzi, K.L.H. Greub, D. Liptzin, C.E. Norris, E.L. Rieke, P.W. Tracy, E. Aberle, O. Bañuelos Tavarez, A.I. Bary, R. L. Baumhardt, A. Borbón Gracia, D.C. Brainard, J.R. Brennan, D. Briones Reyes, D. Bruhjell, C.N. Carlyle, J.H. Crawford, C.F. Creech, S.W. Culman, B. Deen, C.J. Dell, J.D. Derner, T.F. Ducey, S.W. Duiker, R.S. Dungan, M.F. Dyck, B.H. Ellert, M.H. Entz, A. Espinosa Solorio, S.J. Fonte, S. Fonteyne, A.-M. Fortuna, J.L. Foster, A.J. Franzluebbers, L.M. Fultz, A.V. Gamble, C.M. Geddes, D. Griffin-LaHue, J.H. Grove, S.K. Hamilton, X. Hao, Z.D. Hayden, J.L. Heitman, N. Honsdorf, J.A. Howe, J.A. Ippolito, G.A. Johnson, M.A. Kautz, N.R. Kitchen, S. Kumar, K.S. M. Kurtz, F.J. Larney, K.L. Lewis, A.B. Leytem, M.A. Liebig, M. Liebman, A.Lopez Ramirez, S. Machado, B. Maharjan, M.A. Martinez Gamiño, W. May, M.P. McClaran, M.D. McDaniel, N. Millar, J.P. Mitchell, A. Moore, P.A. Moore Jr., M.M. Gutiérrez, K.A. Nelson, E.C. Omondi, S.L. Osborne, D.L. Osmond, L. Osorio Alcalá, E.M. Pena-Yewtukhiw, H.J. Poffenbarger, B. Ponce Lira, J.R. Reeve, T.M. Reinbott, M. Reiter, E.L. Ritchey, K.L. Roozeboom, Y. Rui, A. Sadeghpour, U.M. Sainju, G.R. Sanford, W.F. Schillinger, R.R. Schindelbeck, M.E. Schipanski, A.J. Schlegl, K.M. Scow, L.A. Sherrod, A.L. Shober, S.S. Sidhu, E. Solís Moya, M. St. Luce, J.S. Strock, A.E. Suyker, V.R. Sykes, H. Tao, M.L. Thompson, A. Trujillo Campos, L.L. Van Eerd, N. Verhulst, T.J. Vyn, D.B. Watts, B.B. William, D.L. Wright, T. Zhang, C.W. Honeycutt. 2022. Carbon-sensitive pedotransfer functions for plant available water. Soil Sci. Soc. Am. J. 86:612-629. https://doi.org/10.1002/saj2.20395

Lockard, C.L., C.G. Lockard, W.N. Smith, K.J. Karr, B.P. Holland, A.B. Word, J.L. Foster, and J. S. Jennings. 2021. Effects of roughage type on particle separation, rumination, fiber mat characteristics, in situ degradation, and ruminal fermentation parameters in beef steers. J. Anim. Sci. 99: 1-9. doi.org/10.1093/jas/skab214

Napier,J. J.Lovell, T.Juenger et al. Francis M. Rouquette, Jr. 2022. **A generalist-specialist tradeoff between switchgrass cytotypes impacts climate adaptation and geographic range. PNAS. https://** 10.1073/pnas.2118879119.

Redmon, Larry. 2021. Where Should Forage Courses be Housed? J. Animal Science 99 Issue Supplement 3:100-101.

Redmon, Larry, Tryon Wickersham, and Monte Rouquette, Jr. 2022. In which department should forages be taught? Invited Anim Sci. Translational Animal Science. (accepted, in press).

Rieke, E.L., S.B. Cappellazzi, M. Cope, D. Liptzin, G.M. Bean, K.L.H. Greub, C.E. Norris, P.W. Tracy, E. Aberle, A. Ashworth, O. Bañuelos Tavarez, A.I. Bary, R.L. Baumhardt, A. Borbón, Garcia, D.C. Brainard, J.R. Brennan, D. Briones Reyes, D. Bruhjell, C.N. Carlyle, J.J.W. Crawford, C.F. Creech, S.W. Culman, B. Deen, C.J. Dell, J.D. Derner, T.F. Ducey, S.W. Duiker, R.S. Dungan, M.F. Dyck, B.H. Ellert, M.H. Entz, A. Espinosa Solorio, S.J. Fonte, S. Fonteynez, A.-M. Fortuna, J.L. Foster, A.J. Franzluebbers, L.M. Fultz, Audrey V. Gamble, C.M. Gedde, D. Griffin-LaHue, J.H. Grove, S.K. Hamilton, X. Hao, Z.D. Hayden, J.L. Heitman, N. Honsdorf, J.A. Howe, J.A. Ippolito, G.A. Johnson, M.A. Kautz, N.R. Kitchen, S. Kumar, K.S.M. Kurtz, F.J. Larney, K.L. Lewis, A.B. Leytem, M.A. Liebig, M. Liebman, A. Lopez Ramirez, S. Machado, B. Maharjan, M.A. Martinez Gamiño, W.E. May, M.P. McClaran, M.D. McDaniel, N. Millar, J.P. Mitchell, P.A. Moore, A.D. Moore, M.M. Gutiérrez, K.A. Nelson, E.C. Omondi, S.L. Osborne, D.L. Osmond, L. Osorio Alcalá, P. Owens, E.M. Pena-Yewtukhiw, H.J. Poffenbarger, B.Ponce Lira, J.R. Reeve, T.M. Reinbott, M.S. Reiter, E.L. Ritchey, K.L. Roozeboom, Y. Rui, A. Sadeghpour, U.M. Sainju, G.R. Sanford, W.F. Schillinger, R.R. Schindelbeck, M.E. Schipanski, A.J. Schlegel, K.M. Scow, L.A. Sherrod, A.L. Shober, S.S. Sidhu, E. Solís Moy, M. St. Luce, J.S. Strock, A.E. Suyker, V.R. Sykes, H. Tao, C. Morgan, and C.W. Honeycutt. 2022. Linking soil microbial community structure to activity: a continental scale assessment of reduced tillage. Soil Bio. and Biochem. 168: 108618. https://doi.org/10.1016/j.soilbio.2022.108618

Rouquette, Francis Monte, Jr, Kelli D. Norman, and Charles Long. 2022. Supplementation for Corriente steers stocked on bermudagrass pastures sod-seeded with rye-ryegrass before the feedlot period. Crop, Forage & Turfgrass Management https://doi.org/10.1002/cft2.20150.

Smith WB, JP Banta, JL Foster, **LA Redmon**, TJ Machado, LO Tedeschi, and FM Rouquette 2021. Effects of supplementation of dried distillers grains with solubles to beef steers grazing Coastal bermudagrass on pasture and in feedlot, and carcass characteristics. Applied Animal Science. 37:155-165.

Smith, Gerald Ray and Monte Rouquette. 2022. TX-BHS berseem clover germplasm. J. Plant Registrations. <https://doi.org/10.1002/plr2.20202>

Spurgin, Chelsey L, Josie A Coverdale, Jessica L Leatherwood, **Larry A Redmon**, Amanda N Bradbery, and Tryon A Wickersham. 2021. Effects of crude protein content on intake and digestion of coastal bermudagrass hay by horses. Translational Animal Science*,* 5:3. txab073, [https://doi.org/10.1093/tas/txab073](https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Furldefense.com%2Fv3%2F__https%3A%2F%2Fdoi.org%2F10.1093%2Ftas%2Ftxab073__%3B!!KwNVnqRv!SRZEGtVWrOHNDnfcajuj_bD5u1DnDYUucHDsAwpcmqazIWUwaLT28Dki3jhqlUw-Nbo6iQ%24&data=04%7C01%7Clarry.redmon%40ag.tamu.edu%7Cf4aac10a23624340494f08d9e6b189d2%7C9fd7580a64724d9ca142d131d3a7a116%7C0%7C0%7C637794472466602384%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000&sdata=OZSma3GrhBZ6dUkpYt3SXsZDbakjBoZfFSEWajNVUnI%3D&reserved=0)

Wagner, Kevin L., Terry J. Gentry, R. Daren Harmel, Emily C. Pope, **Larry A. Redmon**. 2021. Grazing effects on bovine-associated and background fecal indicator bacteria levels in edge-of-field runoff. Water. 13:928. https://doi.org/10.3390/w13070928.

Woli, Prem, Francis M. Rouquette, Jr, Charles R. Long, Luis O. Tedeschi, and Guillermo Scaglia. 2022. Modifying the NRC weight gain model to estimate daily gain for stockers grazing bermudagrass in the southern United States. J Anim Sci. skac011, [https://doi.org/10.1093/jas/skac011](https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Furldefense.proofpoint.com%2Fv2%2Furl%3Fu%3Dhttps-3A__doi.org_10.1093_jas_skac011%26d%3DDwMFAg%26c%3DsJ6xIWYx-zLMB3EPkvcnVg%26r%3DZYvM2PBAqX2GHasSqUgVww%26m%3DaBuz8nbkZ60rIz3a_pq3KYI4d-rkGK2dIveFl_qmzs53yGD0GS5JO81W1fOyHl_b%26s%3DJMe3n1s4wyI0h8M3CMyDPy9fc8GGzXoUReNdPAaOwjI%26e%3D&data=04%7C01%7CMonte.Rouquette%40ag.tamu.edu%7Ceb6b9d90a5234d268ed808d9d75f986a%7C9fd7580a64724d9ca142d131d3a7a116%7C0%7C0%7C637777627850784942%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=CwdwQJSRD8xD6CTEmMOPWq%2BF3ge4l57Z1JJGz7z0cDg%3D&reserved=0)

Woli, Prem, Gerald Ray Smith, Charles Long, and Francis Monte Rouquette, Jr. 2022. Assessing cowpea-wheat double cropping strategies in the southern United States using the DSSAT crop model. Agricultural Sciences. (accepted, in press). [https://dx.doi.org/10.4236/\*\*\*.2022.\*\*\*\*\*](https://dx.doi.org/10.4236/%2A%2A%2A.2022.%2A%2A%2A%2A%2A)

*Symposium Proceedings*

Burke, J.A., K.L. Lewis, and **J.L. Foster**. 2021. Nitrogen dynamics following cover crops in Texas High Plains cotton. Beltwide Cotton Conferences Proceedings. Virtual Conference, Jan. 5-7.

Tree legumes as sustainable ecosystem services in sustainable livestock systems. Muir, J.P., C.E. Cooper & V. Corriher-Olson. Proc. XXIV Int. Grasslands Cong. 2021.

Economic injury level for bermudagrass stem maggot (*Diptera: Muscidae*) in bermudagrass forage production in Texas. V. Corriher-Olson, A. Knutson and F. Mitchell. Proc. XXIV Int. Grasslands Cong. 2021.

*Abstracts*

Burke, J.A., K.L. Lewis, J.L. Foster, P. DeLaune, J.W. Keeling. 2022. Benefits and consequences of no-tillage and cover crop use in semi-arid cotton production. 76th Soil and Water Conservation Society International Annual Conference, Denver, CO, Jul. 31-Aug 3. (Abstr.)

Burke, J.A., K.L. Lewis, P. DeLaune, J.L. Foster, and J.W. Keeling. 2022. Benefits and consequences of no-tillage and cover crop use in Texas semi-arid cotton production. Beltwide Cotton Conferences: Cotton Agronomy, Physiology & Soil Conference. San Antonio, TX, Jan. 4-6. (Abstr.)

Foster, J.L. 2022. An update on in vitro and in situ experimental techniques for approximation of ruminal fiber degradation. ASAS-CSAS Annual Meeting and Trade Show, Oklahoma City, OK, 26-30 Jun 2022. (Abstr.)

Gyawali, A.., H.L. Neely, A.P. Smith, J. Pintar, P.E. Bekewe, C.B. Neely, K.L. Lewis, and J.L. Foster. 2021. Assessing soil health in south central United States. ASA-CSSA-SSSA 2021 International Meetings, Salt Lake City, Utah, Nov. 8-11. (Abstr.)

Gyawali, A.J., H.L. Neely, A.P. Smith, J. Pintar, C.B. Neely, K.L. Lewis, and J.L. Foster. 2021. Soil health: Investigating the sample number question. ASA-CSSA-SSSA 2021 International Meetings, Salt Lake City, Utah, Nov. 8-11. (Abstr.)

McLawrence, J., J. I. DuPont, R. Sarkar, P. H. GOWDA, F. Rouquette, B. K. Northup and A. Somenahally (2021). Soil Organic Carbon Stocks in Response to Long-Term Conservation Practices in Grazing Systems. ASA, CSSA and SSSA International Annual Meetings (2020)| VIRTUAL, ASA-CSSA-SSSA.

Meyer, J., A. Bhandari, J.L. Foster, J. McGinty, S.D. Nelson, and J. Landivar. 2021. Effect of cover crops and tillage on soil moisture availability in a semi-arid region in grain sorghum-cotton rotation. ASA-CSSA-SSSA 2021 International Meetings, Salt Lake City, Utah, Nov. 8-11. (Abstr.)

Meyer, J. G. Schuster, J.L. Foster, J. McGinty, S. Abugho, and J. Landivar. 2022. Effect of cover crops, tillage, and residue management on a cotton-grain sorghum rotation in a semi-arid environment. 76th Annual Meeting of the Subtropical Agriculture and Environments Society, Weslaco, TX, Mar. 11. (Abstr.)

Norris, A.B. L.O. Tedeschi, J.L. Foster, C.E. Cooper, and J.P. Muir. 2021. Plant CT influences on the soil environment: Feces, litter, and soil. ASA-CSSA-SSSA 2021 International Meetings, Salt Lake City, Utah, Nov. 8-11. (Abstr.)

Shen, X., M. Clayton, M.J. Starek, A. Chang, R.W. Jessup, and J.L. Foster. 2021. Identification of brush species in southern Texas using Unoccupied Aerial System (UAS). ASA-CSSA-SSSA 2021 International Meetings, Salt Lake City, Utah, Nov. 8-11. (Abstr.)

Valencia, H., K.L. Lewis, and J.L. Foster. 2022. Double-cropping wheat system effects on soil extracellular enzyme activity related to carbon and nitrogen cycling across Texas. 76th Soil and Water Conservation Society International Annual Conference, Denver, CO, Jul. 31-Aug 3. (Abstr.)

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

*Extension Publications*

Banta, J.P., J.M. Bell, V. Corriher-Olson, J.L. Foster, R.L. Noland, and J.K. Smith. 2022. Testing forages and hay for hydrogen cyanide (prussic acid) potential.

Rouquette, Jr., Monte and Gerald Smith. 2022. Long-Term Cow-Calf Performance on Overseeded Bermudagrass Pasture at Different Stocking Rates and Fertility Regimens: 2022 Fertilizer Prices and Costs of Gain. Res. Center Tech Rept. 2022-1

Smith, Gerald and Monte Rouquette, Jr. 2022. Forage Legumes for Texas 2022. Res. Center Tech Rept 2022-2.

Smith, Gerald and Monte Rouquette, Jr. 2022. Winter Pasture Establishment in Warm-Season Perennial Grass Pastures -2022. Res. Center Tech Rept. 2022-3.

Redmon, Larry and Monte Rouquette. 2021. Forages: Who Do They Belong to? Annual Meeting of ASAS, CSAS, SSASAS, 14-17 July, Louisville, KY.

Rouquette, Jr., Monte. 2022. Forage and Pasture Options for Wintering Cattle. Res. Center Tech Rept 2022-4.

*Popular Articles*

Corriher-Olson, V. How to handle hay following a hurricane or flood. Progressive Forage. 2021

Corriher-Olson, V. Increasing Establishment Rate. Progressive Forage. 2021

Corriher-Olson, V. Armyworms march across Texas hayfields, pastures. Texas Farm Bureau News. 2021

Corriher-Olson, V. Flooded: Too much of a good thing. Gulf Coast Cattlemen. 2021

Corriher-Olson, V. Grazing Resources. Angus Beef Bulletin. 2021

Russell, Adam and **V. Corriher-Olson**. Online Pesticide Continuing Education Units Program, Nov 19. AgriLife Today. 2021

Russell, Adam and **V. Corriher-Olson**. Fall armyworms on the march across Texas. AgriLife Today. 2021

Russell, Adam and **V. Corriher-Olson**. Rains, wet conditions delay hay producers. AgriLife Today. 2021

Russell, Adam and **V. Corriher-Olson**. Forage producers face high input costs, drought. AgriLife Today. 2021

Thomas, H. 2022. Drones: The 21st century ranch hand. Progressive Cattle. 24 Jun. <https://www.progressivecattle.com/topics/facilities-equipment/drones-the-21st-century-ranch-hand>

1. **Scientific Outreach Presentations**

Not reported

1. **Disclosures/Patents**

Smith, G.R. and F.M. Rouquette, Jr. 2022. A5989AGLR22 ‘Giant’ Forage Cowpea.

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

Corriher-Olson, V., F.M. Rouquette, Jr., et al. Texas State Soil and Water Conservation Board. 2021-2024. Implementing and Tracking Success of Agricultural Management Measures in Four Texas Watersheds. Total awarded: $ 339,101.

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

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

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

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

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

1. **Graduate Students**

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

*Foster*

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

**Virginia**

1. Impact Nugget

A major research effort at Virginia Tech is testing the idea that ecosystem services provided by tall fescue-dominated grasslands can be improved by increasing the plant biodiversity available to beef cattle and bees. We do this my creating grazed grasslands that contain native warm-season grasses mixed with diverse wildflowers. We have termed this land sharing approach, where beef cattle and bees share the same land replete with warm-season grasses and wildflowers, “Bee-Friendly Beef”. Our goal seeks to improve the output of ecosystem services by providing improved beef cattle production (provisioning service) and generating valuable pollination resources (regulating service) compared with tall fescue-dominated grassland.

2. New Facilities and Equipment

N/A

3. Unique Project Related Findings

Results are still too preliminary

4. Accomplishment Summaries

With cooperators at the University of Tennessee, we have initiated many studies across our two states since 2020. Studies include: 1) grazing experiments to evaluate beef cattle performance and pollinator abundance on biodiverse pastures. 2) on-farm trials where biodiverse pastures have been created on private land to enhance pollinators and honey bee production, and 3) various small-plot experiments where we are trying to determine the most effective way to establish native grasses and wildflowers. Several socio-economic surveys are also on going to evaluate consumer and producer acceptance of these approaches to enhance pasture biodiversity.

5. Impact Statements

Work is still on-going

6. Published Written Works

*(Cite them with CSSA, ASA references format)*

*Refereed publications*

*Proceedings publication*

J. Kubesch, B. Tracy 2022. Biodiverse forage mixtures for bees and beef cattle. *Virginia Tech Shenandoah Valley Agricultural Research and Extension Center 2022 Field Day Proceedings. Aug 3rd 2022 p.19*

*Bulletins and Extension Factsheets*

7. Scientific and Outreach Presentations

 *Abstracts, symposium and conference presentations*

8. Collaborative Grants

9. Graduate students

Jonathan Kubesch PhD – expected graduation date May 2024

Raven Larcom MS – expected graduation date Dec. 2022

Harrison Stewart MS – expected graduation date May 2024

**Michigan**

1. **Impact Nugget**

None.

1. **New Facilities and Equipment**

None.

1. **Unique Project-Related Findings**
* Perennial forage grass varieties exhibit consistent ranking of heading dates across environments.
1. **Accomplishment Summaries**

Fostering resilience and ecosystem services in landscapes by integrating diverse perennial circular systems. Michigan’s role in this multi-institution project is to lead development of the farm-pair network and extension/outreach efforts, while also collaborating in research and education objectives. In 2022 we developed the framework for the farm-pairs and began recruiting farmers. We leveraged additional funding for our research objective from in-state source and established a study in 2022 to evaluate double-cropping alfalfa and silage corn. The sequence is a spring harvest of alfalfa, followed by suppressing alfalfa with a low rate of glyphosate, planting and harvesting silage corn from wide rows in the living alfalfa, followed by a fall alfalfa cutting.

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

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

1. **Impact Statements**
* Ongoing work indicates positive potential for developing a maturity rating system for perennial forage grasses.
1. **Published Written Works**

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

* **Picasso, V., M. Berti**, **K. Cassida**, S. Collier, D. Fang, A. Finan, M. Krome, **D. Hannaway, W. Lamp,** A. Stevens, C. Williams. 2022. Diverse perennial circular forage systems are needed to foster resilience, ecosystem services, and socioeconomic benefits in agricultural landscapes. *Grasslands Research* 1:123-130. <https://doi.org/10.1002/glr2.12020>
* Maciel, I.C.F., *L.R. Thompson, R.M. Martin*, **K.A. Cassida**, J.P. Schweihofer , J.E. Rowntree. 2022. Effects of annual cereal grain and brassica forage mixtures during the last 70 days of the forage-finishing period on forage production, beef steer performance, and carcass characteristics. *Applied Anim. Sci.* 38:222-236. [doi.org/10.15232/aas.2021-02245](https://doi.org/10.15232/aas.2021-02245)
* Maciel, I.C.F., *L.R. Thompson, R.M. Martin*, **K.A. Cassida**, J.P. Schweihofer, J.E. Rowntree. (In Review) Effects of annual cereal grain and brassica forage mixtures during the last 70 days of the forage-finishing period on forage production, beef steer performance, and carcass characteristics. *Applied Anim. Sci.*
* Maciel, I.C.F., J.P. Schweihofer, J.I. Fenton, J. Hodbod, M.G.S. McKendree, **KA. Cassida**, J.E. Rowntree. 2021. Influence of beef genotypes on animal performance, carcass traits, meat quality and sensory characteristics in grazing or feedlot-finished steers. *Transl. Anim. Sci.* 2021.5:1-18. doi.org/10.1093/tas/txab21. IF 1.24.
* *Thompson, L.R*., I.C.F. Maciel, P.D.R. Rodrigues, **K.A. Cassida**, and J.E. Rowntree. 2021. Impact of forage diversity on forage productivity, nutritive value, beef cattle performance and enteric methane. *J. Anim. Sci.* doi.org/10.1093/jas/skab326. IF 1.714.

*Proceedings Publications*

* **Picasso, V, M Berti, K Cassida,** A Finan, **D Hannaway, W Lamp**, A Stevens, and C Williams. 2022. Diverse perennial circular forage systems are needed to foster resilience, ecosystem services, & socioeconomic benefits in agricultural landscapes. *Proc. North Amer. Alfalfa Improvement Conf*. online <https://naaic.org/Meetings/National/2022meeting/P15%20-%20Picasso%20-%20Diverse%20perennial%20circular%20forage%20systems%20are%20needed%20to%20foster%20resilience.pdf/> Lansing, Michigan, June 7-9, 2022. (poster abstract)
* **Cassida K,** P. Kaatz, and M. Jean. 2022. Harvest schedule affects productivity of high-quality alfalfa varieties grown across a latitude gradient in Michigan. *Proc. North Amer. Alfalfa Improvement Conf*. Online <https://naaic.org/Meetings/National/2022meeting/P4%20-%20Cassida%20-%20Harvest%20Schedule%20Affects%20Productivity%20of%20High-Quality%20Alfalfa%20Varieties%20Grown%20Across%20a%20Latitude%20Gradient%20in%20Michigan.pdf/> Lansing, Michigan, June 7-9, 2022.
* **Cassida K,** AP Nejadhashemi, K Dahlin, Y Newman, and B Saravi. 2022. Precision agriculture tools for optimizing alfalfa production and marketing. *Proc. North Amer. Alfalfa Improvement Conf*. Abstract online [https://naaic.org/Meetings/National/2022meeting/LP1%20-%20Cassida%20-%20Precision%20Agriculture%20Tools%20for%20Optimizing%20Alfalfa%20Production%20&%20Marketing.pdf/](https://naaic.org/Meetings/National/2022meeting/LP1%20-%20Cassida%20-%20Precision%20Agriculture%20Tools%20for%20Optimizing%20Alfalfa%20Production%20%26%20Marketing.pdf/) Video online <https://naaic.org/Meetings/National/2022meeting/Videos/Cassida.mp4/> Lansing, Michigan, June 7-9, 2022.
* **Cassida K**, J Hall, Y Hunde, R Kapsenberg, R Lamp, J Magnuson; S Reid; and SR Smith. 2022. Developing a maturity rating index for cool-season forage grasses. *Proc. North Amer. Alfalfa Improvement Conf*. Online <https://naaic.org/Meetings/National/2022meeting/Cassida%20-%20Developing%20a%20Maturity%20Rating%20Index%20for%20Cool-Season%20Forage%20Grasses.pdf/> Lansing, Michigan, June 7-9, 2022.
* **Cassida, KA.** 2022. Scope of forages in Michigan.  *Proc. North Amer. Alfalfa Improvement Conf*. Online <https://naaic.org/Meetings/National/2022meeting/Presentations/W%20-%20Cassida.pdf/> Lansing, Michigan, June 7-9, 2022.
* Bradford B, **K Cassida**, and I Muhammad. 2022. Reduced lignin alfalfa: updates on agronomy and feeding. *Proc. TriState Dairy Nutrition Conf.*, Fort Wayne, Indiana, April 11-13, 2022. <https://viewer.joomag.com/2022-tri-state-dairy-nutrition-conference-april-2022/0614408001649650770?short&>

*Bulletins and Extension Factsheets:*

* **Cassida, K.,** J. Paling, J. Dedecker, & C. Kapp. 2022. *2021 Michigan Forage Variety Test Report.* MSU Forage Factsheet 22-01, 32 pages. Online Feb. 28, 2022. <https://forage.msu.edu/wp-content/uploads/2022/04/2021-Michigan-Forage-Variety-Report-Web-Version.pdf/>

*Farm Press Articles:*

* **Cassida, K.,** J. Paling, and C. Kapp. 2022. 2021 Michigan Forage Variety Test Report. *Michigan Farm News*, Jan. 30, 2022, pp 15-23.
* **Cassida, K**. 2022. Forage Research Update: What’s new at MSU? *Michigan Hay & Grazier*, Winter 2022, p 2.

*Web Articles:*

* **Cassida, K**. 2022. *MSU Forage Connection*. [www.forage.msu.edu/](http://www.forage.msu.edu/) (Website)
* Bradford, B., **K. Cassida** & K Krogstad. 2022. Should dairies utilize grasses to increase forage NDF digestibility? *MSUE Ag News*. Online 8/1/22. <https://www.canr.msu.edu/news/should-dairies-utilize-grasses-to-increase-forage-ndf-digestibility?/>

*Other Creative Works:*

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

*Abstracts and Posters:*

* Eckhardt E, CN Macaluso, RA Ehrhardt, **KA Cassida**, JP Schweihofer, Barbara Makela, AJ Garmyn. 2022. Lamb cover crop grazing and backgrounding impacts on meat quality and composition. Reciprocal Meat Conference, Des Moines, IA, June 12-15, 2022
* Kaur H, M.P. Singh, M. Chilvers, **K.A. Cassida**, C. Difonzo. 2022. Agronomic and pesticide decisions for managing ear rots, mycotoxins and quality in Michigan corn silage. *International Integrated Pest Management Conference*, Denver Feb 28-Mar 3, 2022.
* Ibraheem, M., **K. Cassida**, P. Kononoff, D. Min, K. Jagadish, and B. J. Bradford. 2022. Impacts of reduced-lignin alfalfa on intake, digestibility, and productivity of lactating Holstein cows. *Proc. American Soc. Dairy Sci. Annual Meeting*, June 19-22, 2022, Kansas City, MO.
* *Kaur, H.,* Singh, M. P., Chilvers, M., DiFonzo, C., & **Cassida, K. A.** 2021. Planting Date and Seeding Rate Impacts Ear Rots, Mycotoxins, and Forage Quality in Corn Silage [Abstract]. ASA, CSSA, SSSA International Annual Meeting, Nov. 7-10, 2021, Salt Lake City, UT. <https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/134649>
* *Kaur, H.,* Singh, M. P., Chilvers, M., DiFonzo, C., & **Cassida, K. A.** 2021. Strategies for Managing Mycotoxins, Ear Rots, and Ear Damaging Insects in Corn Silage [Abstract]. ASA, CSSA, SSSA International Annual Meeting, Nov. 7-10, 2021, Salt Lake City, UT. <https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/133244>

*Reports:*

* **Cassida, K.A**. 2022. NCCC-31 Annual Report. Annual Meeting NCCC31, Laramie Wyoming, June 16, 2022.

*Extension presentations:*

* Aug 4, 2022. Cassida. Alfalfa Planting Recommendations. *MSUE Field Crops Virtual Breakfast*. Online <https://www.canr.msu.edu/videos/alfalfa-planting-recommendations/> (83 synchronous attendees)
* June 2, 2022. Cassida with MSUE Specialist Team. Hot Topics Q&A. *MSUE Field Crops Virtual Breakfast*. Online <https://www.canr.msu.edu/videos/hot-topic-q-a-session/>
* Aug 2, 2022. Cassida. Forage Research Update-UPREC. Board of Trustees facility tour. UPREC. (15 attendees)
* April 14, 2022. Cassida. Hayfield fertility on a budget. *MSUE Field Crops Virtual Breakfast*. Online <https://www.canr.msu.edu/videos/hayfield-fertility-on-a-budget/> (138 synchronous attendees)
* April 13, 2022. Barry Bradford & Cassida. Reduced lignin alfalfa: updates on agronomy and feeding.. *TriStates Dairy Nutrition Conference*, Fort Wayne IN, April 11-12, 2022. (INVITED SPEAKER, ~100 attendees)
* March 14, 2022. Kim Cassida & Erin Burns. Weed Control in Hay Fields and Pastures. *2022 MSUE Field Crops Webinar Series - Two for the Price of One: Conversations in Row Crop Agriculture*. Online <https://www.canr.msu.edu/videos/field-crops-webinar-weed-management-in-hay-and-pasture-fields-cassida-burns/>
* Mar. 17, 2022. Cassida. Forage Research Update: Grass-Legume Mixtures. *Great Lakes Forage & Grazing Conference*, St. John, MI. (40 attendees)
* Mar. 17, 2022. Cassida. Forage Research Update: cover crop grazing works! *Great Lakes Forage & Grazing Conference*, St. John, MI. (40 attendees)
* Jan 8, 2022. Cassida. In search of the perfect sheep pasture. *Shepherds Weekend, MSPA Annual Conference* Jan 7-9, 20221. Lansing, MI. (INVITED SPEAKER)
* Dec. 20, 2021. **\*Cassida**. Forage Update. *MSUE Field Crops Integrated Pest Management Update-Breakout Session.* East Lansing, MI. (18 participants) Breakout impact not assessed.
* Dec. 2, 2021. **\*Cassida.** Lessons from Alfalfa and Forage Trials. *Ontario Forage Council Forage Focus Webinars* (online). Online 12/9/21. <https://www.youtube.com/watch?v=_yBcT3peUEw/> (~40 synchronous views, 65 online views, 3/1/22) Stakeholder group: farmers in Ontario. Impact assessment unavailable. (INVITED SPEAKER)
1. **Collaborative Grants** *(NCCC31 members bolded)*
* **Cassida KA** and E Burns. 2022. Intercropping Alfalfa and Corn Silage to Build Soil Health. Project GREEEN GR22-071. $79,399. 2022-2024. FUNDED. *(Leveraged to* ***Picasso*** *et al.,* Fostering resilience and ecosystem services in landscapes by integrating diverse perennial circular systems*, NIFA* 2021-68012-35917*)*
* Isaacs, K., E. Olsen, **KA Cassida**, C. Curell. 2022. Evaluating an under-utilized species for climate resilient forage and cover crop options in North Central Region cropping systems. NCR-SARE, $249,932. FUNDED.
1. **Graduate Students**
* Jonathan King (MS in progress)
* Paige Baisley (MS in progress)