2018-19 USDA Central-East Regional Biomass Research Center Accomplishment Report

2018 Accomplishments

Location, location, location: field specific factors affect sustainability. Greenhouse gas emissions associated with crop production vary from farm to farm. ARS scientists in University Park PA and university scientists evaluated the cost and change in greenhouse gas emissions from use of different farm management practices with switchgrass production. We found that soil characteristics along with previous crop history, management practices, and distance to market all affected the combination of practices delivering the lowest cost greenhouse gas mitigation. This finding will inform university, industry, and government agencies of the importance of location specific factors in developing the most cost-effective greenhouse gas mitigation strategies.

Citation: Field, J.L., S. G. Evans, E. Marx, M. Easter, P. R. Adler, T. Dinh, B. Willson, and K. Paustian. 2018. High resolution techno-ecological modeling of a bioenergy landscape to identify climate mitigation opportunities in cellulosic ethanol production. Nature Energy 3:211–219 doi:10.1038/s41560-018-0088-1.

Framework to incentivize adoption of low greenhouse gas emission farm practices. Although N2O is the largest source of greenhouse gas emissions from production of biomass crops and varies greatly from farm to farm depending on soil characteristics, production practices, and climate, this variability is not considered within policy frameworks due to uncertainty in estimation. ARS scientists in University Park PA and university scientists evaluated a farm level framework to reduce uncertainty in estimating N2O to increase adoption of low greenhouse gas emission practices. We found that this framework was effective at reducing the uncertainty of N2O estimation and could provide significant incentives at the farm for adoption of low greenhouse gas emission practices. Incorporation of this framework could increase the adoption of mitigation strategies which reduce N2O emissions associated with crop production.

Citation: Gao, S., P.L. Gurian, P. R. Adler, S. Spatari, R. Gurung, S. Kar, S. M. Ogle, W. J. Parton, S. J. Del Grosso. 2018. Framework for improved confidence in modeled nitrous oxide estimates for biofuel regulatory standards. Mitig Adapt Strateg Glob Change 23:1281–1301. https://doi.org/10.1007/s11027-018-9784-1.

Nitrous oxide emissions from grasslands on marginal lands. N2O is the largest source of greenhouse gas emissions from production of biomass crops and although perennial grasses can provide significant water quality benefits on conservation reserve program (CRP) land, if they are located in wet areas in the landscape, they can lead to high emissions of N2O. ARS scientists in University Park PA and university scientists found that although N2O emissions were high in the wet areas of the fields, it was similar in most areas of the landscape compared with previous grassland vegetation present in CRP land, while producing much greater biomass. This finding will inform government agencies developing greenhouse gas mitigation strategies that targeted mitigation strategies can address most emissions.

Citation: Saha, D., A. R. Kemanian, F. Montes, H. E. Gall, P. R. Adler, and B. M. Rau. 2018. Lorenz curve and Gini coefficient reveal hot spots and hot moments for nitrous oxide emissions. Journal of Geophysical Research: Biogeoscience 123:193–206. https://doi.org/10.1002/2017JG004041.

Crop legacy affects N_2O emissions accounting. There are several methods to estimate N_2O emissions used for life cycle assessments (LCAs), however, they have not been evaluated for multiple crop rotations. ARS scientists in University Park, PA, in collaboration with university scientists, evaluated several methods for estimating N_2O emissions for grain and sweet sorghum rotations in Uruguay which include different legumes. We have found that when the preceding crop is a legume, N_2O emissions are underestimated when the N_2O estimation methods do not account for legacy nitrogen from preceding crops in the rotation, an error which increases in size with the amount of N fixed by the legume. This finding will inform university, industry, and government agencies to evaluate methods used in estimating N_2O emissions of LCAs for crops in complex rotations

Citation: Adler, P. R., S. Spatari, F. D´Ottone, D. Vazquez, L. Peterson, S. J. Del Grosso, W. E. Baethgen, and W. J. Parton. 2018. Legacy effects of individual crops affect N_2O emissions accounting within crop rotations. GCB Bioenergy 10:123–136. doi: 10.1111/gcbb.12462.

Getting the most of nitrogen fertilizer applied to calendula for industrial oil. Calendula, (pot marigold) is a source of industrial oil traditionally grown on a limited basis for medicinal or ornamental properties but now it is being grown for its oil as an alternative to fossil fuel or as an alternative to volatile organic compounds. However, little was known about the nitrogen fertilizer need to support growing calendula as a commercial oilseed crop. Nitrogen is critical for crop production but can easily be lost over the winter is left behind in the soil. . Plus, nitrogen fertilizer is an expensive input for producers so unused nitrogen represents a reduction in potential profits. A two-year study measuring plant yield and the amount of nitrogen left in the soil was used to make a fertilizer recommendation that supports crop yield without leaving excessive fertilizer behind. The data was added to the ARS Nitrogen Use and Outcomes (NUO net) database. Producers who wish to grow this crop and get the most use of the nitrogen applied will benefit from this research.

Citation: Johnson, J.M., Gesch, R.W., Barbour, N.W. 2018. Limited seed and seed yield response of calendula to applied nitrogen does not justify risk of environmental damage from high urea application rates. Agriculture. 8(40). https://doi.org/10.3390/agriculture8030040. Log# 338895

New oilseed crops show potential for production in saline soils. New oilseed crops integrated into the agricultural landscape can provide numerous environmental and economic benefits. Field margins are potential areas for farmers to incorporate these crops, but these areas can be prone to saline soils that are detrimental to the germination and growth of certain plants. ARS researchers from Morris, Minnesota, demonstrated that camelina and cuphea seed germination tolerate relatively high saline levels, while pennycress and calendula tolerate modest levels, indicating that these new oilseed crops potentially can be produced in field margins. Results benefit the specialty crop industry and farmers, extension specialists, and crop consultants in determining areas to potentially adopt and produce new oilseeds.

Citation: Matthees, H.L., Thom, M.D., Gesch, R.W., Forcella, F. 2018. Salinity tolerance of germinating alternative oilseeds. Industrial Crops and Products. 113:358-367. https://doi.org/10.1016/j.indcrop.2018.01.042. Log# 343389

Dual cropping winter oilseeds with soybean reduces excess soil nitrogen. ARS researchers in Morris, Minnesota, developed strategies for double-and relay-cropping winter camelina and pennycress with soybean to produce two crops in a single season. In collaboration with University of Minnesota scientists, demonstrated that winter camelina and pennycress grown as winter annual crops did a far better job at sequestering excess soil nitrogen in fall and spring than if a sole summer crop of soybean was grown. A single summer soybean crop has been standard practice in the past. Both dual cropping techniques were more productive than mono-cropped soybean, but the best dual-crop system depended on environment. Results will benefit agricultural professionals (i.e., scientists and farmers) exploring cover crops to maximize farming profits while improving the environment.

Citation: Johnson, G.A., Wells, S.M., Anderson, K., Gesch, R.W., Forcella, F., Wyse, D.L. 2017. Yield tradeoffs and nitrogen between pennycress, camelina, and soybean in relay- and double-crop systems. Agronomy Journal. 109:2128-2135. https://doi.org/10.2134/agronj2017.02.0065. Log# 335568

Establishment of winter camelina and pennycress as cover crops. Because of the short growing season in the northern Corn Belt, corn and soybean are often harvested too late for good cover crop establishment. An ARS researcher in Morris, Minnesota, in collaboration with North Dakota State University scientists demonstrated that winter camelina could be interseeded into both standing corn and soybean after the four- to five-leaf stage without harming their yields. Results will help agricultural professionals (i.e., scientists and farmers) refine recommendations for seeding winter camelina as a cover crop in short growing season environments.

Citation: Berti, M.T., Samarappuli, D., Johnson, B.L., Gesch, R.W. 2017. Integrating winter camelina into maize and soybean cropping systems. Industrial Crops and Products. 107:595-601. https://doi.org/10.1016/j.indcrop.2017.06/014. Log# 337274

Microwave pretreatment effectively breaks down biomass. Switchgrass and miscanthus are promising potential sources for bioenergy and value-added products. They are non-edible biomass materials with high total carbohydrate contents. Successful production of biofuels and other bioproducts from biomass requires pretreatment to facilitate conversion. Microwave-based pretreatment is an efficient and effective method for these feedstocks. Microwave treatment enhanced the breakdown of these two biomass feedstocks and efficiency increased as the microwave processing temperature increased. Miscanthus biomass was more vulnerable to breakdown by microwave treatment and was achieved at lower temperatures compared to switchgrass. However, untreated miscanthus biomass produced the highest gas yield. This study demonstrates that microwave pretreatment of biomass in water is a user-friendly and viable alternative to using harsh chemicals to breakdown biomass, but also indicates that all feedstocks do not respond the same to pretreatment.

Citation: Irmak, S., B. Meryemoglu, A. Sandip, J. Subbiah, R. Mitchell, and G. Sarath. 2018. Microwave pretreatment effects on switchgrass and miscanthus solubilization in subcritical water and hydrolysate utilization for hydrogen production. Biomass and Bioenergy 108:48-54. Log# 324347.

NIRS efficiently predicts Napiergrass ethanol conversion. Napiergrass (Pennisetum purpureum) is one of the highest yielding feedstocks for bio-based products and biofuel in the Southern Plains of the United States. Thirty genetically diverse napiergrass accessions were selected from a collection of material originally from Latin America and analyzed for traits that accommodate conversion of the biomass to ethanol. A near infrared reflectance spectroscopy (NIRS) calibration was developed from this material to predict ethanol production, and multiple other traits by separating leaves and stems running chemical analyses in the lab and then correlating with scans from NIRS. The NIRS develops unique reflectance data for individual sources of biomass. This technique makes it 20 to 30-fold faster to analyze different material to determine the effectiveness for conversion to bio-based products. Most of the time, genetic material that had lower biomass had the best traits for conversion to biofuels. However, some napiergrass clones had good quality and quantity. These can be used for genetic improvements by using them as parents or for direct use by producers of biomass for industrial conversion.

Citation: Anderson, W.F., B.S. Dien, S.D. Masterson, and R.B. Mitchell. 2018. Development of near-infrared reflectance spectroscopy (NIRS) calibrations for traits related to ethanol conversion from genetically variable Napier grass (Pennisetum purpureum Schum.). Bioenergy Res. Doi:10.1007/s12155-018-9946-8. 2018. Log# 354992

Insect reduces native grass seed production. The bluestem gall midge is an insect native to the grasslands of North America. It feeds on the developing seeds of warm-season grasses and reduces seed production, but little is known about the insect. We investigated the presence of the bluestem gall midge in big bluestem, sand bluestem, little bluestem, and indiangrass commercial seed production fields in 2001, 2002, 2003, and 2004. Our objectives were to determine the annual production cycle of the bluestem gall midge, the range of the infestation in Nebraska, and estimate its impact on seed production. The midge goes through four generations per year and overwinters in seeds and emerges in mid-June of the following year. The bluestem gall midge was found in five species of warm-season prairie grasses from nine counties in Nebraska, and likely occurs in most places where these grass species exist. The bluestem gall midge damaged a large number of seed from each species and reduced average seed production by 54% in eastern Nebraska. This study is the first to document the negative effects of the bluestem gall midge on the production of viable seed in sand bluestem and indiangrass.

Citation: Raun, E.S., and R.B. Mitchell. 2018. Bluestem gall midge annual production cycle and effects on grass seed production. American Journal of Plant Sciences 9:2077-2085. Doi:10.4236/ajps.2018.910151. Log# 210380

Genomic prediction increases breeding efficiency. Switchgrass is a native tallgrass prairie species that produces large quantities of biomass and requires few inputs. These attributes make it attractive as a forage, for conservation planting, and as a feedstock for biofuel and bioenergy production. Traditional switchgrass breeding requires 3-4 years to complete one cycle of trait improvement. In order to more efficiently breed switchgrass for bioenergy production, the long breeding cycle needs to be shortened. This can be accomplished by a process called genomic selection, which uses dense DNA-based genetic information to predict traits without actually assessing them in each generation, thus reducing the generation interval. Four methods were used to predict different switchgrass traits related to bioenergy from genetic information. We also measured the impact of population, breeding history, and degree of relatedness on prediction accuracy. Depending on the trait and population, prediction accuracy ranged from very high to insignificant. Not accounting for origin, breeding history, and degree of relatedness increased apparent accuracy, but most of this increase was due to structural differences between populations rather than differences among them. Breeders can use this information to make informed decisions about the best candidates to propagate for improvement of targeted traits.

Citation: Fiedler, J.D., C. Lanzatella, S.J. Edmé, N.A. Palmer; G. Sarath, R. Mitchell, and C. Tobias. 2018. Genomic prediction accuracy for switchgrass traits related to bioenergy within differentiated populations. BMC Plant Biology 18(1):142. doi:10.1186/s12870-018-1360-z. Log# 349091

Pelletizing biomass is expensive but improves conversion to ethanol. Tall native prairie grasses are considered as future bioenergy crops for production of alcohols for transportation fuels. The US government estimates that up to 187 million tons of perennial grasses can be harvested annually from land too poor in quality for production agriculture. Whereas trucks filled with chopped grass or bales can be only filled 50%, pelleted materials significantly increase the amount of plant material that a truck can carry. In this study, ARS and a commercial partner investigated using grasses to make higher density pellets. Twenty tons of each big blue stem, switchgrass, and a low diversity mixture of grasses that seeks to emulate in part a natural pasture were pelletized at a commercial feed operation. We came to four conclusions. Pellets can be conveniently manufactured without the use of an external chemical binder. This is important because bioenergy and hay are different in composition because hay is harvested in spring/summer and bioenergy crops in fall/winter. The pellets bulk density was 407% greater than the beginning material and this is sufficient to allow trucks to be fully loaded. Pelletization required drying the grass, heating it, and subjecting it to high pressure. This process led to a 1-3% loss of carbohydrates, which warrants further study. However, pellets converted more efficiently than chopped grasses into sugars and ethanol. This led to the central finding that pellets and chopped grasses had the same production yields and that pellets were easier to store and process. Overall pellets are superior to chopped grasses for production of biofuels provided the cost of pelletizing is affordable. This work is of interest to current ethanol producers considering expanding into bioenergy crops and to animal feed producers looking for new sources of biomass.

Citation: Dien, B.S, R. Mitchell, M. Bowman, V. Jin, J. Quarterman, M. Schmer, V. Singh, and P. Slininger. 2018. Bioconversion of pelletized big bluestem, switchgrass, and low-diversity grass mixtures into sugars and bioethanol. Frontiers in Energy Res. doi: 10.3389/fenrg.2018.00129. Log# 352463

Precipitation variability has more effect on yield of upland than lowland switchgrass. Perennial grasses, such as switchgrass, are high in cellulose and an important source of renewable bioenergy. Rainfall amount and its variability among years and among sites, has undefined influences on the fertilizer response of switchgrass productivity. Likewise, global climate models predict changes in rainfall patterns towards lower and increasingly variable soil water availability in several productive areas worldwide. This should have major impacts on the production of biofuel crops. We analyzed annual values for switchgrass production from 48 publications with numerous locations, soil types, switchgrass cultivars, and fertilizer inputs. Lowland ecotypes had doubled production with N rates > 131 kg N per ha per yr, but upland ecotypes showed only 50% increases. The optimum N rate was 30 to 60 kg N per ha per yr for both groups of ecotypes, after which biomass gain per unit of N added decreased. Growing season rainfall, long-term mean annual rainfall and inter-annual rainfall variability differentially affected lowland and upland productivity, depending on the N level. Productivity responses to mean annual rainfall and growing season rainfall were similar for both upland and lowland ecotypes at low N rates. When N increased beyond 60 kg N per ha per yr, lowland ecotypes had a greater growth response to mean annual rainfall than upland ecotypes. Productivity increased with increasing growing season rainfall and mean annual rainfall, and had a positive linear response to mean annual rainfall ranging from 600 to 1200 mm per yr. The N fertilization effect increased at higher levels of mean annual rainfall, more so in lowland than in upland ecotypes. After accounting for mean annual rainfall, sites with higher intern-annual rainfall variability had lower switchgrass productivity than sites with lower intern-annual rainfall variability. In lowland ecotypes, N fertilization mitigated the negative effect of intern-annual rainfall variability on productivity. Higher precipitation increased switchgrass yield more consistently among upland than lowland ecotypes. Increased inter-annual variation in precipitation reduced production of both ecotypes. Predicted changes in the amount and timing of precipitation thus likely will exert greater influence on production of upland than lowland ecotypes of switchgrass.

Citation: Reichmann, L.G., H.P. Collins, V.L. Jin, M.V. Johnson, J.R. Kiniry, R.B. Mitchell, H.W. Polley, and P.A. Fay. 2018. Inter-annual precipitation variability decreases switchgrass productivity from arid to mesic environments. Bioenergy Research 11:614-622. doi/10.1007/s12155-018-9922-3. Log# 349970

Harvest timing and N fertilizer drive biomass yield in native grasses. Warm-season grasses like switchgrass, big bluestem, and indiangrass are native to the US Midwest and have drawn interest as bioenergy crops. These grasses generally have high productivity with minimal amounts of nitrogen fertilizer and are adapted to a wide range of soils, including degraded soils. Further, because they are deep-rooted perennials and store soil carbon they are credited with multiple environmental benefits. Nitrogen fertility and harvest timing are critical management practices of these grasses that are not well understood when growing them on degraded soil landscapes. A study was conducted at four field locations in central and west-central Missouri over two years to evaluate the impact of N fertilizer rate and timing along with the harvest date on biomass yield. Results indicated delaying harvest until late fall or after killing frost (typically November or later) generally gave the best yields. Within the late fall harvest, rates of 60 lbs of

N per acre or more produced the most biomass. In contrast, harvesting in summer and early fall (a two cut management system) or just early fall resulted in lower biomass yield. In a few situations, the optimal nitrogen fertilizer rate varied by harvest timing, but there was no consistent interaction between these two management practices. These results will aid researchers and practitioners in identifying optimal management practices when growing warm-season grasses as bioenergy crops on marginal soils.

Citation: Weerasekara, C., N. Kitchen, S. Jose, P. Motavalli, S. Bardhan, and R. Mitchell. 2018. Biomass yield of warm-season grasses affected by nitrogen and harvest management. Agron. J. 110:890-899. Log# 340463

Breeding has improved switchgrass and big bluestem yield by up to 40%. Switchgrass and big bluestem are two grasses being developed as biomass crops for conversion to bioenergy. A fundamental requirement for this industry is to create new varieties with greater biomass yield potential than is available from existing forage varieties. New candidate varieties of these two grasses were evaluated in field trials for five years at 13 locations, ranging from Nebraska to Pennsylvania and from northern Minnesota, Wisconsin, and Michigan to central Missouri. Significant progress was made by two USDA-ARS breeding programs (Lincoln, NE and Madison, WI) toward improving biomass yield of both grasses, with realized gains as high as 40% greater than existing forage varieties. These results will be of great value to document the performance of new varieties scheduled for public release in the next few years, as well as providing other researchers with a model for testing candidate varieties of perennial grasses.

Citation: Casler, M., K. Vogel, D. Lee, R. Mitchell, P. Adler, R. Sulc, K. Johnson, R. Kallenbach, A. Boe, R. Mathison, K. Cassida, D. Min, J. Crawford, and K. Moore. 2018. 30 years of progress toward increased biomass yield of switchgrass and big bluestem. Crop Sci. 58:1242–1254. Log# 345509

Field drying of biomass crops can be reliably modeled. Moisture content of biomass is an important factor that influences long-term safe storage and processing operations for biofuel production. Temperature, relative humidity, solar radiation, wind, soil moisture, and rainfall are the major factors that affect the field drying of crops. Our objectives were to evaluate the effect of environmental conditions and swath density on switchgrass and corn stover drying characteristics, model development, and validation by conducting field trials for both switchgrass and corn stover. A field drying study was conducted in Iowa and Nebraska to evaluate the effect of environmental conditions and swath density on drying characteristics of switchgrass and corn stover. Environmental conditions such as hourly solar radiation, vapor pressure deficit, average wind speed, rainfall amount, harvesting method, and field operations such as swath density were used as variables for model development. Computer modeling was able to adequately predict the moisture content of switchgrass and corn stover in the field. Hours after harvest, average solar radiation intensity, change in radiation intensity, rainfall, and vapor pressure deficit were the most important factors affecting moisture content. As swath density increased, rate of drying decreased. Rainfall events delayed crop drying by one day to several days depending on the weather conditions after rainfall. Nighttime and early morning dew increased the moisture content in low density swaths of switchgrass and corn stover by 5 to 15%. The models developed will help the biofuel industry make informed decisions for harvesting and collecting switchgrass and corn stover based on forecasted weather conditions in the lower Midwestern states.

Citation: Khanchi, A., S.J. Birrell, and R.B. Mitchell. 2018. Modeling the influence of crop density and weather conditions on field drying characteristics of switchgrass and corn stover using random forest, Biosystems Engineering 169:71-84. Log# 343577

Proper sampling is critical to accurately predict microbial communities in perennial grasses. Properly collecting, processing, and separating samples from experimental fields is an important first step in conducting accurate plant and soil microbial studies. This method provides detail and insight into how to sample and analyze the complex interactions between microbial communities in the roots and soil. This study was conducted in two pure stands of warm-season grasses and a low-diversity grass mixture with two nitrogen fertilizer treatments. First, plants are excavated, the roots are harvested, soil around the roots is collected, and the soil is carefully picked through to remove root material. After surface sterilizing the roots and sieving the soil, DNA is extracted and sequenced. These methods provide the ability to isolate specific sample types and to visualize how the microbial community composition differs in various samples. There are significant differences in microbial communities of the roots compared to the soil. These methods provide a step-by-step approach to isolate samples, DNA, and analyze microbial DNA and the communities they represent.

Citation: McPherson, M., P. Wang, E. Marsh, R. Mitchell, and D. Schachtman. 2018. Isolation and analysis of microbial communities in soils, rhizosphere, and roots in perennial grass experiments. J. Vis. Exp. 137 e57932, doi:10.3791/57932. Log# 350167

2019 Accomplishments

Crop residue removal in high-production systems can supply feedstocks for both livestock and bioenergy. Management practices that can ameliorate potential negative effects on soil properties from crop residue removal is needed. Researchers in Ft. Collins, Colorado and Lincoln, Nebraska evaluated long-term sites in the central Plains to determine how soil organic carbon and soil microbial biomass is affected by crop residue removal. Crop residue removal decreased soil organic carbon and soil aggregation with the majority of declines occurring near the soil surface. Crop residue removal did not change soil microbial biomass or soil microbial communities. Results suggest that conservation tillage practices alone are inadequate to maintaining important soil properties for the central Plains. The use of cover crops or manure may be required in addition to conservation practices if crop residue removal occurs.

Citation: Stewart, C.E., D.L. Roosendaal, A.J. Sindelar, E. Pruessner, V.L. Jin, and M.R. Schmer. 2019. Soil property changes from stover removal under irrigation: a multi-location assessment. Soil Sci. Soc. Amer. J. 83:733-742.

Increasing farmers' willingness to grow biofuel crops. Oilseed crops such as camelina, carinata, and canola have good properties for bio-based jet fuel. However, production of biofuel from oilseeds will not be successful unless farmers are willing to grow them. Collaborative research including ARS scientists at Mandan, ND, and scientists at Kansas State University, Iowa State University, Berlin, Germany, and Ghent, Belgium identified factors significantly affecting willingness of farmers to grow oilseed crops for biofuel in the western U.S. The results are useful to stakeholders in the biofuel industry in understanding and reducing barriers to oilseed production. Among the actions that could be taken to increase farmers' willingness to grow oilseeds for biofuel are establishment of nearby crushing facilities and increasing farmer experience with oilseed production.

Citation: Embaye, W.T., Bergtold, J.S., Archer, D.W., Flora, C., Andrango, G.C., Odening, M., Buysse, J. 2018. Examining farmers' willingness to grow and allocate land for oilseed crops for biofuel production. Energy Economics. 71:311-320. https//doi.org/10.1016/j.eneco.2018.03.005. Log# 338264

Winter cover crop and relay-crop options to maintain productivity and economic returns. Growing crops to maintain cover over the winter could provide environmental benefits, but it is challenging in Northern climates with added costs of winter crop establishment and potential negative crop yield impacts. ARS scientists in Morris, MN and Mandan, ND, along with scientists from University of Minnesota and University of Wyoming evaluated yields and economics of four winter cover options compared to two winter fallow treatments in a spring wheat-soybean rotation at three sites in Minnesota. The winter cover options included camelina and pennycress that were relay-cropped with soybean and harvested over the soybean canopy, and traditional cover crops winter rye and forage radish that were not harvested. Total seed yields for the relay-crop options were similar to and sometimes exceeded those of soybean grown alone in the traditional winter fallow treatments. Net incomes for the relay-crop options were also similar to soybean grown alone, so these may be the most economically favorable winter cover options for producers.

Citation: Ott, M.A., Eberle, C.A., Thom, M.D., Archer, D.W., Forcella, F., Gesch, R.W., Wyse, D.L. 2019. Economics and agronomics of relay-cropping pennycress and camelina with soybean in Minnesota. Agronomy Journal. 111:1281-1292. https://doi.org/10.2134/agronj2018.04.0277. Log # 352272

Oilseed suitability for western wheat-growing regions. Oilseed crops belonging to the mustard family provide rotational benefits to wheat and are being targeted for biofuel feedstock production in the western U.S. wheat-growing regions. However, little is known about which species produces the greatest yield or is best suited for a given region across the dryland wheat producing area of the U.S. ARS scientists from Morris, MN, Pendleton, OR, Peoria, IL, Sidney, MT, Mandan, ND, Ames, IA, Temple, TX, Akron, CO along with scientists from the University of Idaho investigated the productivity and drought tolerance of 12 mustard varieties from six species across eight environments spanning four ecoregions within the U.S. Environment greatly affected oilseed performance. Both seed and oil yields increased with increasing seasonal rainfall. Generally, commercial varieties of canola (Brassica napus) and Indian mustard (Brassica juncea) produced the greatest oil yields, in part due to their high seed oil concentration. However, some species such as Ethiopian mustard (Brassica carinata) performed well in certain environments but poorly in others. Research identified varieties well suited for certain environments but also showed that more work is needed to improve the oil concentration of some high seed yielding varieties to make them more useful as biofuel feedstock.

Citation: Gesch, R.W., Long, D.S., Palmquist, D.E., Allen, B.L., Archer, D., Brown, J., Davis, J.B., Hatfield, J.L., Jabro, J.D., Kiniry, J.R., Vigil, M.F., Oblath, E., Isbell, T. 2019. Agronomic performance of Brassicaceae oilseeds in multiple environments across the western United States. BioEnergy Research. 1-15. https://doi.org/10.1007/s12155-019-09998-1. Log# 361454

Renewable jet fuel from oilseed feedstocks replacing fallow. Jet fuels have been made from oilseeds crops and could be used to replace fossil fuels. However, there are concerns about "food versus fuel" and land use competition for these fuels. ARS scientists in Mandan, ND, along with scientists at Michigan Tech, the U.S. Department of Transportation, and Phitsanulok, Thailand looked at growing the oilseeds in place of fallow in non-irrigated areas of the U.S. Northern Great plains to avoid displacing other crops and improve sustainability. Results showed that growing oilseeds in place of fallow could boost farmer incomes in the region and reduces fossil fuel use by a factor of 3.0-3.5 with significant reductions in greenhouse gas emissions and increases in soil carbon.

Citation: Shi, R., Archer, D.W., Pokharel, K., Pearlson, M.N., Lewis, K.C., Ukaew, S., and Shonnard, D.R. 2019. Analysis of renewable jet from oilseed feedstocks replacing fallow in the U.S. Northern Great Plains. ACS Sustainable Chemistry & Engineering 7:18753-18764. https// doi.org /10.1021/acssuschemeng.9b02150

Global soil carbon dataset developed for perennial crops. Perennial crops comprise 30% of global croplands, and as such, have a significant effect on the quality of agricultural land. Despite their importance to agriculture and energy production, the effects of perennial crops on soil properties are not fully understood. This issue is compounded by the fact that there are few data sets documenting ecosystem services under perennial crops. Therefore, a global database on soil organic carbon (SOC) change resulting from perennial crop cultivation was compiled. The database includes information from over 1600 paired-comparison empirical values from 180 different peer-reviewed studies, 709 sites, on 58 different perennial crop types, from 32 countries in temperate, tropical and boreal areas. The database also contains information about climate, soil characteristics, management and topography. As the first such global compilation of SOC data under perennial crops, the database has potential to support multiple modeling and research efforts aimed at informing policy development to enhance the delivery of ecosystem services from agricultural lands.

Citation: Ledo A., J. Hillier, P. Smith, E. Aguilera, S. Blagodatsky, F. Brearley, A. Datta, E. Diaz-Pines, A. Don, M. Dondini, J. Dunn, D. Feliciano, R. Lang, M. Liebig, M. Llorente, Y.L. Zinn, N. McNamara, S. Ogle, Z. Qin, P. Rovira, R. Rowe, J. Vicente-Vicente, J. Whitaker, Q. Yue, and A. Zerihun. 2019. A global, empirical, harmonised dataset of soil organic carbon changes under perennial crops. Sci. Data 6:57. https://doi.org/10.1038/s41597-019-0062-1. Log# 363199.

Bioenergy grasses reduce erosion nutrient loss on marginally-productive cropland. Growing native perennial warm-season grasses for bioenergy is often credited as a way to improve water quality and reduce soil erosion on marginally-productive cropland. However, direct measurements of the impacts of these dedicated bioenergy crops is limited. We studied how dedicated bioenergy crops impacted runoff, sediment and nutrient losses and related near-surface soil properties as compared to no-till corn on an eroded soil in southwestern Iowa and a center pivot corner in east central Nebraska. Treatments were Liberty switchgrass and no-till continuous corn at the Iowa site, and Liberty switchgrass, Shawnee switchgrass, low diversity warm-season grass mixture, and a corn-soybean rotation at the Nebraska site. We simulated rainfall for 1 h and measured water quality parameters. Warm-season grasses tended to reduce runoff compared with corn on marignally-productive lands. In the center pivot corner, perennial grasses reduced sediment and nutrient losses in runoff and increased soil aggregate stability compared with corn. Switchgrass grown in an eroded soil in Iowa tended to reduce sediment loss. Based on these two locations, growing perennial grasses for bioenergy can improve water quality in marginally productive croplands but their effectiveness appears to be site-specific.

Citation: Acharya, B.S., H. Blanco-Canqui, R.B. Mitchell, R. Cruse, and D. Laird. 2019. Dedicated bioenergy crops and water erosion. J. Environmental Quality. 48:485-492. doi: 10.2134/jeq2018.10.0380. Log# 350779

Monocultures and mixtures have similar yields across environments. Biomass yield is the primary factor influencing bioenergy feedstock production. Our objective was to compare the biomass yield potential of the best commercially available perennial warm-season grasses in monocultures and mixtures across an environmental gradient in the Midwest, U.S.A. Switchgrass, big bluestem, indiangrass, sideoats grama, and *Miscanthus* x *giganteus* (Mxg) were grown in monocultures and mixtures. Biomass yield across locations and years averaged 9.5 Mg ha^{-1}. For monocultures, average yields were 11.1, 11.0, and 8.0 Mg ha^{-1} in IL, NE, and IA, respectively. For mixtures, average yields were 10.3, 9.9, and 7.6 Mg ha^{-1} in IL, NE, and IA, respectively. At all locations, M×g and Kanlow N1 switchgrass had the highest yields in monocultures. Our 6 year results suggest mixtures provided no yield advantage over monocultures for bioenergy feedstocks in Illinois and Nebraska. However, variation in seasonal and annual precipitation may provide conditions that allow warm-season grass mixtures to produce more consistent biomass yields and confer resilience to environmental fluctuation. This experiment improves our understanding of the biomass production potential of native warm-season grasses in monocultures and mixtures in the Corn Belt.

Citation: Lee, M., R.B. Mitchell, E. Heaton, C. Zumpf, and D.K. Lee. 2019. Warm-season grass monocultures and mixtures for sustainable bioenergy feedstock production in the Midwest, USA, Bioenergy Res. 12:43–54. Doi:10.1007/s12155-018-9947-7. Log# 358133

Riparian grasslands provide economic and water quality benefits. Grassland buffers can improve water quality, but it is typically hard for farmers to capture the economic value without enrolment in government conservation programs. ARS scientists in University Park PA and university scientists found that highly productive switchgrass and Miscanthus had similar water quality impacts as the grass mixture enrolled in conservation practices; although nitrogen fertilizer didn't increase yields, it did increase water quality impacts. This finding shows that there are potential economic opportunities for biomass production in riparian buffer grasslands while maintaining water quality benefits.

Citation: Rau, B. M., P. R. Adler, C. J. Dell, D. Saha, A. R. Kemanian. 2019. Herbaceous perennial biomass production on frequently saturated marginal soils: Influence on N_2O emissions and shallow groundwater. Biomass Bioenergy 122:90–98. https://doi.org/10.1016/j.biombioe.2019.01.023.

Add value to soybean production by pressing oil on-farm. There has been interest in producing biofuel from oil seed crops for use on farms, however little guidance is available on where this may be profitable. ARS scientists in University Park PA and university scientists found that the profitability and carbon footprint of processing soybeans on-farm improves as farm location moves towards the coastal Atlantic and Gulf regions where the economic value of the meal is higher. This finding will help farmers determining if pressing their own soybeans may add value to their farm and how much the carbon footprint of their farm can be reduced by using the soybean oil in their farm machinery.

Citation: Adler, P. R., M. E. Hums, F. M. McNeal, and S. Spatari. 2019. Evaluation of environmental and cost tradeoffs of producing energy from soybeans for on-farm use. J Cleaner Production 210:1635-1649. https://doi.org/10.1016/j.jclepro.2018.11.019.

Spring camelina responses to nitrogen fertilizer in USA northern Corn Belt. Camelina is a source of industrial and food oils that can be grown in the USA. The seed oil is a feedstock for producing "green" jet fuel that meets all the ASTM standard for aviation fuel. However, little was known about the nitrogen fertilizer needed to support growing camelina as a commercial oilseed crop. Nitrogen is critical for crop production, but if it is left behind in the soil can easily be lost over the winter. Plus, nitrogen fertilizer is an expensive input to producers so unused nitrogen represents reduction in potential profits. ARS researchers at the Morris, Minnesota, conducted a two-year study measuring plant yield and the amount of nitrogen left in the soil was used to make a fertilizer recommendation that support crop yield without leaving excessive fertilizer behind. The data was added to the ARS Nitrogen Use and Outcomes (NUO net) database. This information is used for producers who wish to grow this crop and get the most use of the nitrogen applied.

Citation: Johnson, J.M., Gesch, R.W., Barbour, N.W. 2018. Spring camelina N rate: Balancing agronomics and environmental risk in United States Corn Belt. Archives of Agronomy and Soil Science. https://doi.org/10.1080/03650340.2018.1519803. Log# 340185

Harvesting corn residues did not change nitrous oxide emission. Corn is one of the most common grown crops grown in the USA. It grows quickly and produces roughly equal amount of grain and residue. The residue also called stover is the non-grain material including leaves, cobs and stalks. Stover can be used to make fuel grade ethanol, but harvesting stover can change soil properties, which could also change how much nitrous oxide is released from soil. Nitrous oxide is potential greenhouse gas that contributes to global warming. ARS researchers at the Morris, Minnesota, monitored the amount of nitrous oxide released from two fields. Nitrous oxide was released after applying nitrogen fertilizer and in the early spring when the soil thawing. However, the same amount of nitrous oxide was released among the three stover harvest treatments. This means harvesting stover did not increase nor decrease how much of this gas was released. These results are important for the bioenergy industry, feedstock producers and for modelers seeking to understand what may happen as stover harvest become more common.

Citation: Johnson, J.M., and Barbour, N.W. 2019. Stover harvest did not change soil nitrous oxide emissions in two Minnesota fields. Agronomy Journal. 111:143-155. https://doi.org/10.2134/agronj2018.09.0591. Log# 357390

Understanding how managing corn residue impacts soil organic carbon modeling and metanalyses. The amount of corn residue that can be harvested without causing undesirable impacts on soil properties can be challenging. Empirical data from long-term studies on the impact of corn residue harvest was used in a process-based model and as a part of a meta-data analysis. ARS researchers at the Morris, Minnesota, collaborated on empirical, modeling and meta-data analysis found that harvesting corn stover while maintaining soil organic properties. The meta-analyses suggested that soil organic content (a measure of soil health) was more sensitive to stover harvest rate than to tillage. These analyses can help determine science-based policy recommendations for harvesting crop residue for bioenergy.

Citations: Gollany, H.T., Nash, P.R., Johnson, J.M., and Barbour, N.W. 2019. Predicted annual biomass input to maintain soil organic carbon under contrasting management. Agronomy Journal. 111(5):1-11. https://doi.org/10.2134/agronj2018.10.0698. Log# 359166
Xu, H., Sieverding, H., Kwon, H., Clay, D., Stewart, C.E., Johnson, J.M., Qin, Z., Karlen, D.L., and Wang, M. 2019. A global meta-analysis of soil organic carbon response to corn stover removal. Global Change Bio. Bioen. 00:1-19. https://doi.org/10.1111/gcbb.12631. Log# 362154

Novel winter-hardy oilseeds help reduce nutrient loss. Winter cover cropping is a proposed strategy to reduce nutrient loss. However, establishing cover crop systems in the Upper Midwest is challenging due to lack of winter-hardy crop varieties and incentives for adoption. ARS researchers in Morris, Minnesota, determined that two novel over-wintering oilseed crops, winter camelina and pennycress, sequestered available N and reduced soil water nitrate from fall through spring soybean planting. These novel winter oilseeds provide an economic incentive for their adoption as they can be grown and harvested for their seed-oil. These results will help researchers, land managers and policy makers to develop, support and promote winter oilseeds as a cover cropping strategy that can provide both environmental and economic benefits.

Citation: Weyers, S.L., Thom, M.D., Forcella, F., Eberle, C.A., Matthees, H.L., Gesch, R.W., Ott, M., Feyereisen, G.W., Strock, J.S., Wyse, D. 2019. Potential for nutrient loss reduction in cover cropped systems in the Upper Midwest. Journal of Environmental Quality. 48(3):660-669. https://doi.org/10.2134/jeq2018.09.0350. Log# 358114

Upland and lowland switchgrass cultivars differ in their ability to withstand plant pathogen attacks. Switchgrass is a native perennial that can provide a sustainable supply of biomass on marginal lands. This biomass can have multiple end uses, including those as a feedstock for bioenergy. Possible molecular dynamics that drive these differences in non-infected plants have not been assessed. Here, the 4th emerging leaf from greenhouse grown Kanlow (lowland) and Summer (upland) switchgrass cultivars were collected from emergence through leaf senescence. RNA extracted from these leaves were subjected to high-throughput next generation sequencing. Data analyses indicated similar and cultivar-specific changes in gene expression. Overall development of leaf functions and transition to senescence were similar; however, Kanlow plants had a much greater number of expressed genes that could be involved in defense against pathogens. These data suggested that Kanlow plants could provide useful traits for the continued improvement of switchgrass germplasm with improved disease resistance.

Citation: Palmer, N.A., R.V. Chowda-Reddy, A. Muhle, S. Tatineni, G. Yuen, S. Edme, R. Mitchell, and G. Sarath. 2019. Transcriptome divergence during leaf development in two contrasting switchgrass (Panicum virgatum L.) cultivars. PLoS ONE 14(9):e0222080. Log# 363224

Genetics provide new insights into predicting switchgrass yield. Finding the specific genes that adapt plants to their environments is a central goal of plant biology, and critical to breeding improved crops for agricultural production. This study tests for specific genes (‘loci’) that underlie adaptation to the environment (‘local adaptation’) in switchgrass, an emerging biofuel crop and dominant tallgrass species. The study assessed genetic variation at 10 locations spread across a large regional gradient in the range of switchgrass from Texas to South Dakota, USA. This is one of the largest studies to date of genetic controls of plant adaptation to the environment. The study identified loci related to biomass yield and found that that most loci contributed to local adaptation at some sites but were neutral in their contribution to adaptation at others. Few loci caused negative effects. By identifying genetic loci related to biomass yield across a large portion of the range of switchgrass, these results will inform breeding of new locally adapted varieties of switchgrass.

Citation: Lowry, D., J.T. Lovell, L. Zhang, J. Bonnette, P.A. Fay, R.B. Mitchell, J. Lloyd-Reilley, A.R. Boe, Y. Wu, F.M. Rouquette Jr., R.L. Wynia, X. Weng, K.D. Behrman, A. Healey, K. Barry, A. Lipzen, D. Bauer, A. Sharma, J. Jenkins, J. Schmutz, F.B. Fritschi, and T.E. Juenger. 2019. QTL x environment interactions underlie adaptive divergence in switchgrass across a large latitudinal gradient. PNAS 116:12933-12941. Doi:10.1073/pnas.1821543116. Log# 359944

Virulent pathogen combinations can improve resistance evaluation in switchgrass. Switchgrass and millets can be co-infected by Panicum mosaic virus (PMV) and its parasite virus, satellite panicum mosaic virus (SPMV). Proso millet is a convenient surrogate host for evaluating viral diseases of switchgrass. Viral infection can significantly affect plant growth, biomass yield and quality. If infection is severe, it can even result in the death of the plant. Virus particles are composed of a proteinaceous exterior (coat protein) which encloses the viral genetic material. Frequently, the amino acid sequence of the viral coat protein can determine the severity of infection. Co-infection with PMV and SPMV can exacerbate plant damage, depending on the source of the viral isolates. In this study, different combinations of PMV and SPMV isolates were used to define the disease responses of host plants. SPMV isolated from Kansas (SPMV-KS) was more virulent than one isolated from Texas, SPMV-Type, when co-inoculated with PMV. Two specific amino acids of the coat protein that differed between SPMV-KS and SPMV-Type were responsible for the increased infectivity of SPMV-KS relative to SPMV-Type. Now, the most virulent combinations of PMV and SPMV can be used to define resistance mechanisms in switchgrass and to develop switchgrass germplasm with improved virus resistance.

Citation: Rekalakunta Venka, C., Palmer, N.A., Edme, S.J., Sarath, G., Kovacs, F., Yuen, G., Mitchell, R., Tatineni, S. 2019. A two amino acid difference in the coat protein of satellite panicum mosaic virus isolates is responsible for differential synergistic interaction with panicum mosaic virus. Molecular Plant-Microbe Interactions. 32:479-490. https://doi.org/10.1094/MPMI-09-18-0247-R.2019. Log# 357031

Native warm-season grasses are adapted to late spring freeze. Native perennial warm-season (C_4) grasses are used for grazing and haying and are a primary focus for future biofuel production. Typically, these grasses emerge from winter dormancy in April and accumulate most of their biomass during summer. Spring hard freeze injury to C_4 perennial grasses is rare and lacking in the literature. Our objective was to document how a rare hard freeze during spring affects warm-season perennial grasses in the central USA. On 2 May at midnight, air temperature near Mead, Nebraska fell to 27° F and remained below freezing until 8:00 am on 3 May. During the last 50-years at this site, a minimum temperature of 32° F on or after 3 May occurred 16 times, but a minimum temperature of 27° F on or after 3 May occurred only twice. Leaf tips turned black 4-d after freezing and had complete browning, rolling, and drying 14-d after freezing. As the growing season progressed, plant growth and development appeared normal. We believe this is the first report of warm-season prairie grass responses to a spring hard freeze after significant spring growth. Plant recovery to this spring hard freeze demonstrates the resilience of these prairie grasses. These rare spring hard freezes had short-term impacts on the native grasses but did not reduce growth and yield for forage or bioenergy later in the growing season.

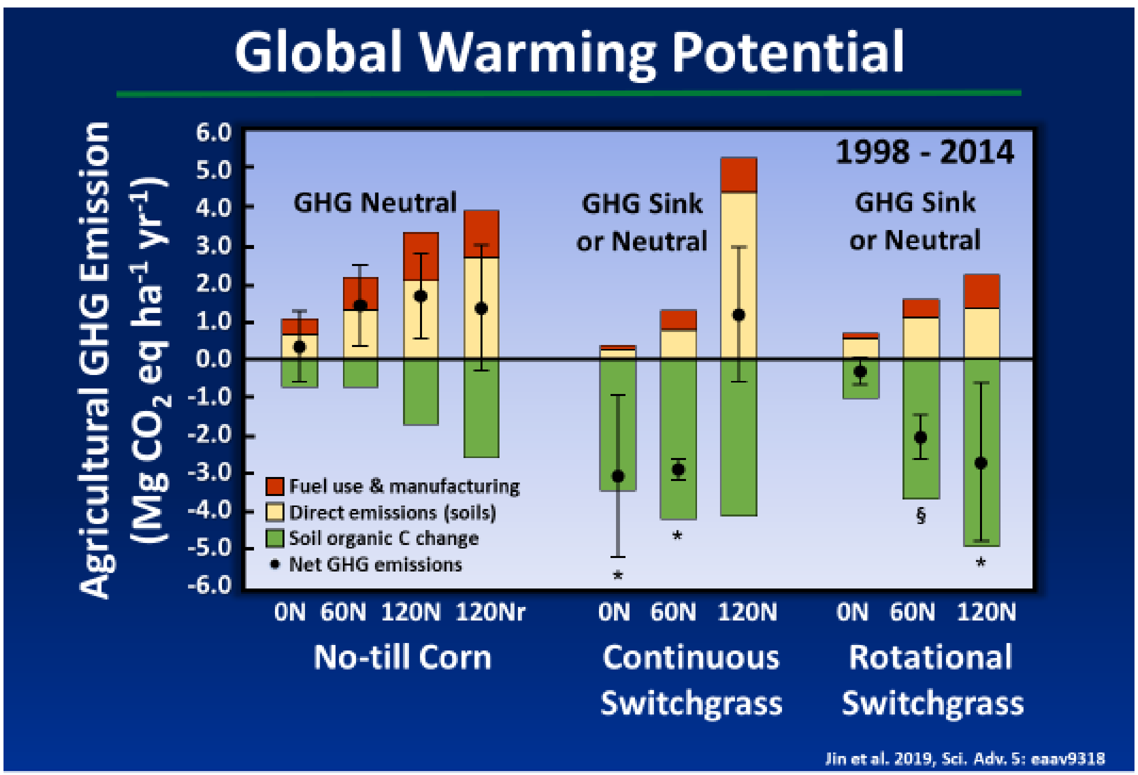
Citation: Mitchell, R.B., and D.D. Redfearn. 2019. Observations of spring hard freeze injury to C_4 perennial grasses native to the Great Plains, USA. American Journal of Plant Sciences. Doi:10.4236/ajps.2019.105052. Log# 361305

Nitrogen-use efficiency is an important trait for breeding improved bioenergy grasses. Development of perennial biomass cropping systems is focused on maximizing biomass yield with minimum inputs, particularly nitrogen (N) fertilizer. Historical breeding efforts have focused on increasing biomass yield but have ignored N-use efficiency. This study quantified the increased N demand associated with realized gains in biomass yield from big bluestem and switchgrass breeding programs. Nitrogen demand was highly variable across locations and years. Increases in N demand were closely associated with realized gains in biomass yield and were observed for all types of switchgrass (upland, lowland, and hybrid) as well as for big bluestem. Attenuation of these responses will require alternative breeding schemes that are focused on evaluation of switchgrass genotypes and progeny under low-N conditions and include a high throughput tissue N analysis as a component of future selection criteria, designed to develop new cultivars with high biomass yield and low tissue N.

Citation: Casler, M.D., D.K. Lee, R.B. Mitchell, P.R. Adler, R.M. Sulc, K.D. Johnson, R.L. Kallenbach, A.R. Boe, R.D. Mathison, K.A. Cassida, D.H. Min, and K.J. Moore. 2019. Nitrogen demand associated with increased biomass yield of switchgrass and big bluestem: implications for future breeding strategies. BioEnergy Research. 13:120-131. Doi:10.1007/s12155-019-10081-y. Log# 362953

<u>Bio-based energy is key to developing a globally sustainable low-carbon economy.</u>
Lignocellulosic feedstock production on marginally productive croplands is expected to provide substantial climate mitigation benefits, but long-term field research comparing greenhouse gas (GHG) outcomes during the production of annual versus perennial crop-based feedstocks is lacking. Here, we show that long-term (16 years) switchgrass (*Panicum virgatum*) systems mitigate GHG emissions during the feedstock production phase compared to GHG-neutral continuous corn under conservation management on marginally productive cropland. Increased soil organic carbon was the major GHG sink in all feedstock systems, but net agronomic GHG outcomes hinged on soil nitrous oxide emissions controlled by nitrogen (N) fertilizer rate. This long-term field study is the first to demonstrate that annual crop systems maintain and perennial grass systems mitigate atmospheric GHG contributions during the agronomic phase of bioenergy production, providing flexibility for land-use decisions on marginally productive croplands.

Citation: Jin, V.L., M. Schmer, C. Stewart, R. Mitchell, C. Williams, B. Wienhold, G. Varvel, R. Follett, K. Vogel, and J. Kimble. 2019. Management controls the net greenhouse gas outcomes of growing bioenergy feedstocks on marginally-productive croplands. Science Advances. 5:9318 doi:10.1126/sciadv.aav9318. Log# 359192



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