Sustainable Agriculture

2017 Research Accomplishments

USDA
Agricultural Research Service
Plains Area

Sustainable Farming

COLORADO

Adaptation of Dryland Cropping Systems for the Central Great Plains Region to Extreme Variation of Weather and Climate

Central Great Plains Resources Management Research Unit, Akron, CO
Project Number: 3010-12210-003-00-D
Lead Scientist: Merle Vigil
Team Members: Maysoon Mikha, Francisco Calderon, David Nielsen

Defining a dryland grain sorghum production function for the Central Great Plains. Grain sorghum is a potentially productive dryland crop for diversifying Central Great Plains cropping systems. ARS researchers in Akron, Colorado, found a strong linear relationship between water use and yield. The yield increased by 33.1 kg/ha per mm of water use (13.4 bu/A per inch of water use). This production function was used to estimate yields using a long-term precipitation record that predicted the probability of producing at least a grain yield of 4000 kg/ha (64 bu/A) would be 18% if available soil water at planting was 111 mm (4.4") and 92% if available soil water at planting was 259 mm (10.2"). The water use-yield production function and the probability graphs generated by this project will help farmers determine the risk involved in incorporating grain sorghum production into their cropping systems.

Intensifying a semi-arid dryland crop rotation by replacing fallow with pea. Substituting pea production for the fallow period in a wheat-corn-proso millet-fallow (WCMF) dryland rotation in the semi-arid central Great Plains could make more efficient use of precipitation while protecting the soil against erosion. However, the water use by the pea may reduce subsequent wheat and corn yields and reduce net income. ARS researchers in Akron, Colorado, found that replacing the fallow period with pea production reduced yields of wheat and corn that followed pea, but did not affect millet

yields. The net income for the WCMP rotation was 32% lower than for the WCMF rotation. Replacing the fallow phase with pea production could only be recommend as an alternative rotation if pea seed costs and nitrogen fertilizer applied to the following wheat crop could be reduced.

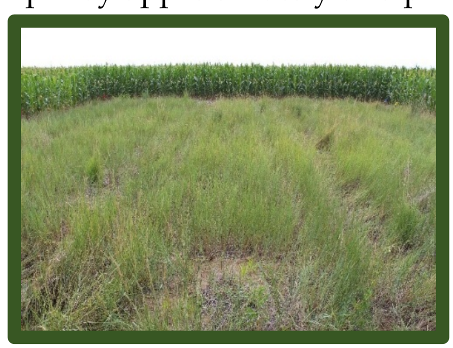
Water use and environmental parameters influence proso millet yield. Proso millet is a highly adapted, water use efficient crop for diversifying Central Great Plains cropping systems. ARS researchers in Akron, Colorado, defined a water use/yield response of 32.57 kg/ha per mm of water use (13.2 bu/A per inch of water use). However, there were many years in which the millet yields obtained were far below what would be expected based on the amount of water use. Important factors that were found to influence the yield, in addition to growing season water use, were plant available water in the 0-120 cm soil profile (0-4 ft), precipitation received from 12-18 August (which increased yield), number of days in July and August with maximum temperature greater than 95 degrees F, and daily average wind run and maximum wind gust during the week before swathing (which decreased yield). These results suggest that closing the yield gap for proso millet production could likely result from efforts to breed for enhanced shattering resistance and heat tolerance, and from production methods that improve precipitation storage efficiency during the non-crop period prior to millet planting and increase available soil water at millet planting.

Measurement of labile organic matter carbon in soil using infrared spectroscopy. ARS researchers in Akron, Colorado, in collaboration with university scientists, documented the variability of labile soil organic matter carbon (C) across a diverse set of soils spanning the continental U.S. Labile soil organic C is the soil C that provides plant nutrients during crop growth, and is the soil C that is easily lost with tillage. Labile soil C is a Natural Resource Conservation Service (NRCS) proposed indicator for soil quality. This research encompasses the analysis of a large collection of soils from several long-term studies in which permanganate oxidizable C (POXC) was measured as a metric for labile soil organic C. We also analyzed these soils using infrared spectroscopy to explore if spectroscopy could be used to quickly and inexpensively estimate labile organic C. The results showed that POXC is a sensitive measure of soil labile organic C, with a wide variation across different soils and land management types. This work also demonstrated that infrared spectroscopy is a worthwhile approach to measure soil labile C, instead of the more laborious wet chemistry laboratory procedures. The quick methods developed in this research will enable national efforts to quickly and reliably estimate soil quality, saving time and money, while obtaining an understanding of individual soil productivity and resilience.

Defined the stability of wheat yields in various dryland rotations. ARS researchers in Akron, Colorado, evaluated 24 years of wheat yield data from eight different dryland wheat rotations using eight yield stability indicators. They found that the stability of wheat yield was dominated as expected by those rotations that had fallow in them. The most stable rotations all had summer fallow in them. Wheat millet fallow (WMF) was more stable then wheat corn fallow (WCF) and wheat corn millet fallow (WCMF). The least stable rotations were those with the highest rotation intensity (continuously cropped) WMF, WCMF and wheat-corn-millet-pea (WCMPea). This work provides producers the expected risk for wheat yield success and failure and wheat yield stability among various rotation options used in the region.

Documented mineralization model accuracy as an aid for making reliable fertilizer recommendations. The actual amount of nitrogen (N) made available during the cropping season when crop residues and organic matter decomposes is elusive. The difficulty is decomposition is a microbial process that is mediated by soil moisture, soil temperature and the chemical composition of the crop residues. In addition, how the crop residues are managed has an effect on the rate of decomposition. If the crop residues are left standing intact (with no-till) less decomposition will occur than if they are buried and broken up by tillage. Because of this complexity, ARS researchers in Akron, Colorado, in collaboration with researchers at the University of Georgia tested a simulation model that takes all of these factors into account. The model was able to reliably and accurately assess N release and N tied up by microbial activity under both field and laboratory conditions. The simulation model is now integrated into the University of Georgia's fertilizer recommendation procedures with their soil testing laboratory.

Quantification of manure application effects on soil properties of eroded land. ARS researchers in Akron, Colorado, compared the effect of the establishment of native grass and native grass legume mixtures, and the application of beef manure on eroded land. The scientists found that after six years, that six to nine tons of manure application reduced the surface soil pH by approximately two pH units. As expected soil organic carbon, total N, metal availability, and soil P all increased with increasing manure application rate. The ARS scientists concluded that manure addition greatly improved soil nutrient status. On the other hand the legume grass mixtures and conventional chemical fertilizer treatments had little



effect on soil quality or nutrient status. It was concluded that the legume and grass mixtures may require longer than six years to effect a change on soil quality in this eroded soil. This research shows the quantitative value of manure as a complete nutrient source over commercial chemical fertilizers.

Improved Management to Balance Production and Conservation in Great Plains Rangelands

Rangeland Resources & Systems Research Unit, Fort Collins, CO
Project Number: 3012-21610-001-00-D
Lead Scientist: Justin Derner
Team Members: Dana Blumenthal, Lauren Porensky, John Tatarko, Liwang Ma, David Hoover, Dannele Peck, David Augustine

Seventy-year experiments reveal that grazing intensity determines the balance between cool-season and warm-season grasses in the Western Great Plains. Sustainable rangeland management requires knowledge of plant community responses to different livestock management strategies over long (multi-decadal) time scales. ARS researchers in Fort Collins, Colorado, and Cheyenne, Wyoming, capitalized on two 70+ year experiments to examine the long-term effects of livestock grazing on plant communities

in northeastern Colorado. Western Great Plains plant communities are relatively unaffected by livestock grazing in the short-term (one to two decades), but the abundance of weedy forbs substantially increased in areas not grazed for seven decades. Moderately and heavily grazed areas had similar mixtures of warm- and cool-season grasses after 70+ years of grazing, whereas plant communities with light grazing were similar to long-term ungrazed areas with more cool-season grasses and weedy forbs. Findings suggest that at least a moderate level of grazing is needed to maintain dominant grasses and resist invasion of non-native plants in these western Great Plains rangelands. Ranchers, the Natural Resource Conservation Service (NRCS), the Forest Service (FS), other state and federal land management agencies, and environmental, non-governmental organizations (e.g., The Nature Conservancy) now have quantitative measures of temporal plant community change associated with long-term livestock grazing strategies. These results are being incorporated by the NRCS into revised state-and-transition models of rangeland dynamics, which will enhance land manager decision-making for the provision of desired ecosystem goods and services from semiarid, western rangelands.

Elevated CO_2 and warming increase productivity and favor cool-season grasses in Great Plains rangeland. Semi-arid rangelands are likely to be sensitive to changes that influence water availability, including elevated atmospheric carbon dioxide (CO_2), which increases plant water use efficiency, and warming, which increases evapotranspiration. ARS researchers in Fort Collins, Colorado, with collaborators from the University of Wyoming, used a seven-year experiment to directly test how elevated CO_2 and warming influence native mixed-grass rangeland. These two global changes, when combined, increased plant productivity, particularly in dry years when forage is most limiting for livestock production. At the same time, however, both soils and plants contained less nitrogen, which may limit the quality of forage available for livestock. Plant communities also changed, with perennial cool-season grasses becoming progressively more abundant over the course of the experiment and perennial warm-season grasses and forbs declining. These results indicate that CO_2 and warming together are likely to have neutral to positive effects on forage resources in the northwestern Great Plains, a key prediction for ranchers and land management agencies, such as the Natural Resource Conservation Service (NRCS), and the Forest Service (FS).

Management Practices for Long Term Productivity of Great Plains Agriculture

Soil Management and Sugarbeet Research, Fort Collins, CO
Project Number: 3012-11120-001-00-D
Lead Scientist: Jorge Delgado
Team Members: Catherine Stewart, Stephen Del Grosso, Daniel Manter

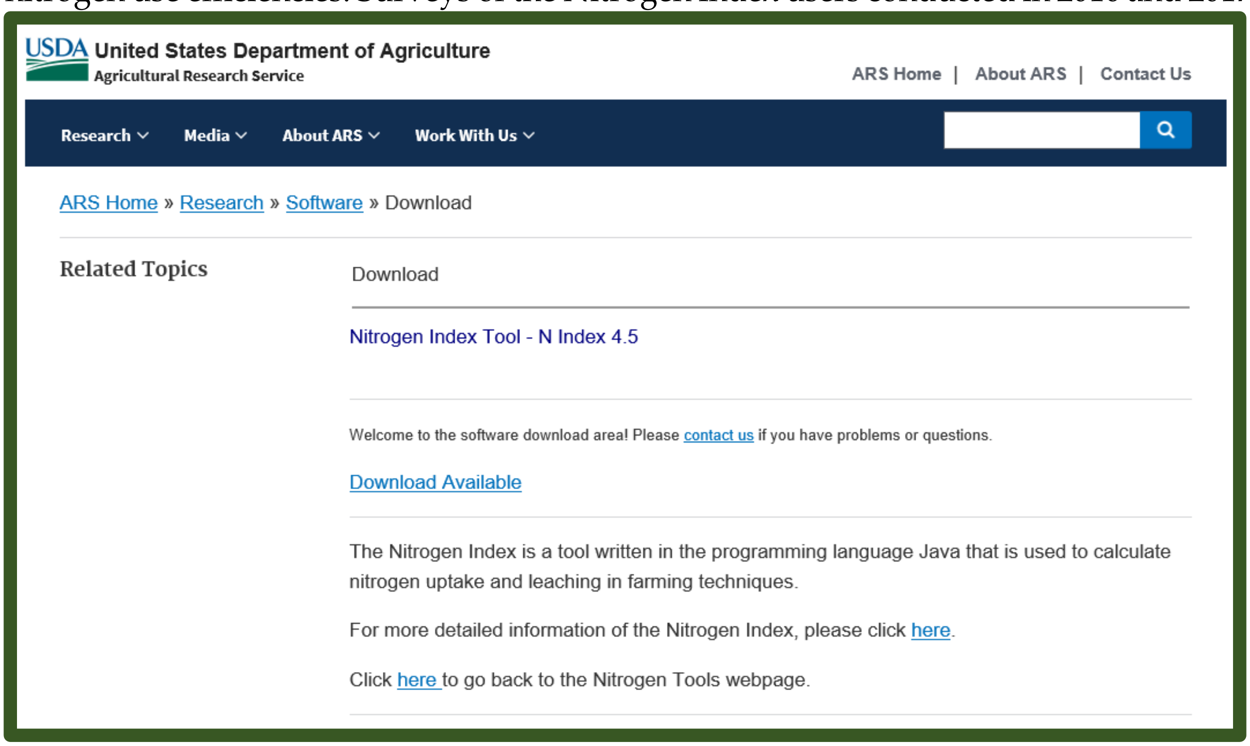
myPhyloDB
a local web server for the storage and analysis of metagenomic data

myPhyloDB — a cutting-edge tool to aid the standardization, normalization, and technology transfer of metagenomics data. The advent of next-generation sequencing has led to a dramatic increase in analysis of genetic material for microbial populations from a variety of sources (e.g., soil, human, animal). However, current analysis platforms do not allow for the convenient storage or standardization necessary for efficient technology transfer and cross-study analyses. An ARS researcher in Fort Collins, Colorado, developed myPhyloDB to fill the need for a database that includes soil biology and soil biology responses to management. This new web-based tool is a significant accomplishment that provides an easy-to-use graphical interface and adds new functionality to the DNA sequence processing capabilities of Mothur – the most widely cited bioinformatics program (4000+ citations). The first version of myPhyloDB has been downloaded or distributed via CD-ROM to more than 100 different research groups, from fields ranging from soil microbial ecology to human health and nutrition to help them resolve scientific problems. The web-based site has had 1,616 visitors from at least 73 countries.

Greenhouse gas
Reduction through
Agricultural
Carbon
Enhancement
network

The greenhouse gas reduction through agricultural carbon enhancement network (GRACEnet) project. There is a need to improve the functionality of GRACEnet by addressing widescale agricultural management impacts on soil carbon and greenhouse gas (GHG) emissions. An ARS researcher in Fort Collins, Colorado, is the chair of the GRACEnet steering committee, which has contributed to historical GRACEnet product developments such as the establishment of field/laboratory measurement protocols, a standardized Excel data entry template, software to perform quality control of data entry, and a web-accessible GRACEnet database. The public portal of the data management system was improved during FY 2018 and integrated with the Natural Resource and Genomics Data Systems server. This portal now contains data from 17 ARS locations with more than 450,000 total records including 116,000 soil GHG (greenhouse gas) emission measurements and 83,000 soil measurements. Data generated by the GRACEnet project increased the accuracy of GHG emission estimates reported in the U.S. national GHG inventories, including the latest EPA (Environmental Protection Agency) inventory published during FY 2017. Additionally, project data have been used to develop scaling factors to quantify the GHG reductions for improved management practices imbedded in decision support tools. GRACEnet data are now being used to validate the underlying models used by the Natural Resources Conservation Service (NRCS) Carbon Management Evaluation Tool [COMET] - Farm decision support tool.

The nitrogen index. One problem of agricultural systems that receive nitrogen inputs is the need for quick tools that can assess how management practices and management decisions can contribute to reduced losses of reactive nitrogen and increased nitrogen use efficiencies. An ARS researcher in Fort Collins, Colorado, developed the Nitrogen Index 4.5.1, which includes different versions of the tool for California, Kentucky, South Dakota, Mexico, the Caribbean, Ecuador, Brazil, Bolivia, and other regions and is available online for download by users at http://www.ars.usda.gov/npa/spnr/nitrogentools. This tool can be used to conduct quick assessments of the effects of management practices on nitrogen use efficiencies. Surveys of the Nitrogen Index users conducted in 2016 and 2017



indicate that the tool is being used to develop nutrient management and conservation management plans for farmers from the USA and other countries. Historically, the Nitrogen Index has been downloaded or distributed over 2,190 times in 65 countries and used for at least 1,800 farmers covering over 150,000 acres. Additionally, professors use the Nitrogen Index as a teaching tool for 1,285 undergraduate students and 364 graduate students, and impacted at least 566 professors, crop consultants, or other professional peers (national and international). The tool was downloaded about 125 times during FY 2017 and used by at least 324 farmers on 39,000 acres and by 229 undergraduate students, 78 graduate students, and 177 peers.

Improved method to calculate biofuel carbon intensity. Biofuels are increasingly being used as substitutes for petroleum based liquid fuels. Regulatory frameworks, such as the US Renewable Fuel Standard, mandate greenhouse gas reduction targets for biofuels including ethanol derived from corn and diesel derived from soybean. However, commonly used methods to calculate the carbon footprint of these crops do not account for all of the important agronomic variables that influence emissions. An ARS scientist in Fort Collins, Colorado, collaborated with ARS and university partners to develop a new method that better accounts for how management practices interact with soil type and weather to control emissions. The new method provides an opportunity for producers to maximize monetary credits available for biofuel feedstock production and incentivizes practices such as improved fertilizer management that reduce the overall environmental impact of these systems.

DayCent model testing and application in western Oregon. A unique accomplishment of a study published in Agronomy Journal was to use the model to simulate changes in soil carbon under different management practices using field data from long term (more than 80 years) conventional till wheat/fallow plots in Oregon. The model was capable of representing the observed large losses of soil carbon for plots that received no fertilizer or where residue was burned, moderate carbon losses in plots that were amended with synthetic fertilizer or pea vine residue, and carbon gains for plots fertilized with cattle manure. The model also correctly represented the observed higher yields of plots that received fertilizer compared to plots that were not fertilized. The model then was used to predict future changes in soil carbon up to the year 2080. Model results suggest the plots that were losing carbon would continue to do so under conventional tillage, but the rate of loss should decrease as soil carbon levels approach a new equilibrium. For the manure plots that were gaining carbon, the model predicts that additional carbon gains would be minimal and a new equilibrium would be reached in about the year 2020. In contrast, if the plots were converted to no till, the model predicts small to moderate C gains, depending on residue management, for plots that were amended with fertilizer, pea vine, or manure, and minimal gains for the zero-fertilizer treatment. The model will be a valuable tool to recommend management practices that increase carbon sequestration in this region of the USA.

Improving the Sustainability of Irrigated Farming Systems in Semi-Arid Regions

Water Management and Systems Research Unit, Fort Collins, CO
Project Number: 3012-13000-010-00-D

Lead Scientist: Louise Comas
Team Members: Huihui Zhang, Kendall DeJonge, Sean Gleason

Assessed linkages among plant physiological systems and plant performance under water stress. ARS researchers in Fort Collins, Colorado, discovered that the decline of hydraulic, photosynthetic, and stomatal systems in maize is closely aligned during water stress. This study provides a contextual framework to guide plant geneticists and breeders in improving crop productivity under water stress. This study also demonstrates the coordination of broad physiological systems in maize during stress and suggests that improvements to one trait in isolation of other linked traits (e.g., cold shock proteins, photosynthetic efficiency, membrane integrity) may result in small improvements to plant performance under drought, but that an approach that embraces the "whole-plant" perspective will be needed before marked improvements in drought tolerance are achieved.

MONTANA

Adaptive Rangeland Management of Livestock Grazing, Disturbance, and Climatic Variation

Range and Livestock Research Unit, Miles City, MT
Project Number: 3030-21630-003-00-D
Lead Scientist: Lance Vermeire
Team Members: Kurt Reinhart, Richard Waterman, Matthew Rinella, Mark Petersen

Medusahead is among the most ecologically and economically damaging invasive weeds of the western U.S. ARS researchers in Miles City, Montana, collaborating with industry and university partners, discovered a completely novel approach for managing this invasive annual grass. The herbicide aminopyralid applied at a very low rate just prior to medusahead flowering drastically reduced seed production in the current generation of plants and reduced cover to nearly zero in the subsequent generation of plants. Controlling medusahead with this

treatment increased production of desired forage grasses, sometimes dramatically. Results were consistent across eight sites distributed across a wide geographical area. Compared to other treatment options, this new approach is less expensive, provides better control of the invader and is more beneficial to desirable forage species.

The 17 western states in the contiguous U.S. averaged 4.6 million acres burned in each of the last 5 years. In addition to costs ranchers face in replacing infrastructure, natural resource agencies often require removal of grazing for 1-3 years after fire. Resulting annual costs in rented pasture alone exceed $54 million. ARS researchers in Miles City, Montana, in cooperation with the U.S. Forest Service determined northern mixed prairie can be grazed the first growing season after spring wildfire without loss in plant production or negative changes in the plant community. Fire increased plant production 56% the year of the wildfire and yielded slightly more or similar production as nonburned sites with a history of light to moderate grazing the second and third years after fire. A companion study demonstrated that plant response to fire was similar whether sites were mowed in June, August, and October, or not mowed after fire. Neither complete rest nor seasonal delays in grazing are necessary for maintenance of plant productivity and species composition in northern mixed-grass prairie following spring wildfire. Results were similar to recent research from the same lab indicating northern mixed prairie is resistant to grazing after summer fire. Results are assisting natural resource agencies with grazing management decisions after fire, and reducing pasture costs for ranchers affected by wildfire. Resulting research papers have been used for popular articles in Ag Research, The Furrow, and On Pasture magazines.

Development of Ecologically-Sound Pest, Water and Soil Management Practices for Northern Great Plains Cropping Systems

Agricultural Systems Research Unit, Sidney, MT
Project Number: 3032-13210-006-00-D
Lead Scientist: William Stevens
Team Members: Upendra Sainju, Jalal Jabro, Brett Allen

Jet fuel from 18 cool-season oilseed feedstocks evaluated in a semi-arid environment. Renewable jet fuel feedstocks can potentially offset the demand for petroleum-based transportation resources and diversify cropping systems. However, identifying suitable feedstock supplies remains a primary constraint to adoption. ARS researchers in Sidney, Montana, conducted a 4-yr study to investigate the yield potential of six winter- (*Brassica napus, Brassica rapa, Camelina sativa*) and 12 spring-types (*Brassica carinata, Brassica juncea, B. napus, B. Rapa, C. sativa, Sinapis alba*) of cool-season oilseed feedstocks in eastern Montana dryland cropping systems. A camelina variety named 'Joelle' was the only fall-seeded variety that survived the typically harsh northern Great Plains winters. Hail storms caused up to 95% yield loss in spring camelina types in 2 of 4 years in the study, but the fall-seeded 'Joelle' was harvested before the hail occurred showing the benefit of an early maturing crop in regions prone to late season hail. Identification of this winter-hardy variety will provide a beneficial option for diversifying dryland cropping systems and mitigating the risk of crop failure. Across all species and varieties, seed yields ranged from about 200 to 2000 kg/ha. Overall, winter camelina (1400 kg/ha) in addition to spring types of B. napus (1900 kg/ha), B. carinata (1300 kg/ha), and camelina (1800 kg/ha) showed the best potential for jet fuel feedstocks in the semi-arid northern Great Plains, USA.

No-till soybean as a reliable alternative crop in for diversifying irrigated sugar beet cropping systems. Sugar beet production in the Missouri River Basin has typically been dominated by two-year sugar beet-small grain rotations. Diversifying sugar beet systems will increase sustainability but alternative crop options are limited in the short growing season of the northern Great Plains. ARS researchers in Sidney, Montana, recently showed that food-grade soybean is a potential rotation crop that could provide a relatively high return while diversifying the system. In a 7-year study, irrigated soybean yield was consistently around 50 bushels per acre when planted no-till into barley stubble or following corn after stover removal. Baling barley straw before planting soybean did not affect yield compared to planting into full barley residue; however, soybean yield was reduced by 10% when planted into full corn residue rather than after stover removal. Researchers concluded that food-grade soybean provides sugar beet growers with an excellent low-input alternative crop to help diversify their cropping system. Benefits include consistent and favorable economic return, lower overall fertilizer inputs, lower tillage and labor costs, and enhanced soil quality. Risks include a potential for greater root and crown rot caused by the *Rhizoctonia* fungus for which both soybean and sugar beet are a host, though no increase in disease incidence was observed in the 8-year study.

Enhanced root biomass with intermediate wheatgrass. Perennial grass offers many advantages as a source of hay for livestock or biomass for lingo-cellulosic biofuel

production. One potential advantage is improved soil carbon levels compared to annual crops. Maintaining soil organic matter content is difficult in northern Great Plains dryland production areas due to the semi-arid environment. Returning crop residues to these soils helps maintain soil quality by sequestering carbon. However, when aboveground biomass is removed from perennial grass crops for use as hay or bioenergy feedstock, roots become the main source of carbon input for soil carbon sequestration. Information on root biomass and root/shoot ratios of perennial grasses in the northern Great Plains environment is needed to determine how biomass harvesting affects soil carbon. ARS researchers in Sidney, Montana, reported that intermediate wheatgrass produced greater root biomass than smooth bromegrass or switchgrass. They found that root biomass and root/shoot ratio were fourteen and eight times, respectively, greater in perennial grasses than annual spring wheat. In situations where aboveground biomass is removed for bioenergy or hay production, intermediate wheatgrass can provide more carbon inputs for soil carbon sequestration than smooth bromegrass, switchgrass or annual small grain crops.

An innovative passive capillary lysimeter for measuring deep water percolation and nitrate leaching. Preventing nitrate transport through the soil profile and leaching into groundwater begins with effective water management practices but quantifying the effects of these practices on water and nitrate movement is challenging. ARS researchers in Sidney, Montana, developed a novel, state-of-the-art automated passive capillary water lysimeter (PCAP) which features a collection system that is more durable and sophisticated than previously reported designs. This innovative lysimeter allows real-time monitoring and estimating of drainage water volume and flux and operates without the need of costly and time-consuming manual support methods. This automated design provides a more efficient and cost effective means of estimating nitrate leaching than other designs. Using this technology, researchers can more accurately determine the effects of management practices on fertilizer and irrigation water efficiencies. Information derived from this research using these lysimeters will help farmers optimize crop yield while avoiding groundwater contamination.

Legume-based crop rotations enhance nitrogen uptake reduce nitrogen loss. Inefficient nitrogen use by crops results in increased soil residual nitrogen accumulation which can be lost to the environment through leaching, volatilization, denitrification, and surface runoff. ARS researchers in Sidney, Montana, reported that legume-based dryland crop rotations reduced fertilizer nitrogen inputs and residual soil nitrogen available for environmental loss due to increased crop nitrogen uptake and soil nitrogen immobilization compared with nonlegume monocropping, especially in ecologically-based no-tillage cropping systems. Producers can reduce the cost of nitrogen fertilization and environmental nitrogen loss and enhance crop nitrogen removal by adopting crop rotations that include both legumes and non-legumes.

NEBRASKA

Management and Soil Resource Evaluation to Enhance Agricultural System Resilience and Sustainability

Agroecosystem Management Research Unit, Lincoln, NE

Project Number: 3042-11210-002-00-D
Lead Scientist: Marty Schmer
Team Members: Virginia Jin, Brian Wienhold

Long-term no-till and stover retention each decrease the global warming potential of irrigated continuous corn. Agricultural production systems can help reduce global warming by storing carbon in soils. Management practices, however, can add greenhouse gases into the atmosphere and counteract the benefit of soil carbon storage. Limited information is available for irrigated row-crop systems. Crop residue removal in high-level production systems such as those under irrigation can supply feedstocks for both livestock and bioenergy. The use of no-till is often recommended as a companion practice for removing crop residues. ARS researchers in Lincoln, Nebraska, found that in a long-term irrigated continuous corn system, all management systems were net greenhouse gas producers and so had limited potential to decrease global warming. ARS researchers also found that there was no global warming benefit to using both no-till and residue retention practices together. Instead using either conservation practice reduced the amount of greenhouse gases released to the atmosphere compared

to more conventional practices (disk tillage, residue removal). Although this irrigated corn system did not store carbon, conservation management practices could provide other benefits to producers, such as decreased soil erosion and increased soil health.

Corn residue utilization by livestock in the United States. Corn residue grazing or harvest provides a simple and economical practice to integrate crops and livestock. Limited information is available on how widespread corn residue utilization is practiced

by U.S. producers. USDA researchers in Lincoln, Nebraska, and Washington D.C., summarized corn producer responses on corn grain and residue management practices. An estimated 10 million corn acres were grazed following grain harvest. The majority of grazed corn residue occurred in Nebraska, Iowa, South Dakota and Kansas. Corn residue harvests predominately occurred in the central and northern Corn Belt with an estimated 3.2 million tons of corn residue harvested and baled from approximately 2 million acres. Results highlight the importance of corn residue for U.S. livestock particularly in the western Corn Belt.

Switchgrass contributions to soil organic carbon, deep soil microbial community composition, and root biomass. More than 50% of the world's soil carbon stocks reside below one foot from the soil surface, but relatively little is known about the importance of rhizodeposit carbon and associated microbial communities in deep soil processes. ARS researchers in Lincoln, Nebraska, and Ft. Collins, Colorado, evaluated a lowland and upland switchgrass ecotype for variability in plant root biomass and subsequent carbon cycling as well as soil microbial community abundance and composition. The lowland ecotype had three times the root biomass with coarser root architecture compared with the upland ecotype but the upland ecotype maintained its root biomass throughout an extreme drought event. Root-derived carbon inputs influence soil C processes and switchgrass ecotype interactions with the soil microbial community plays an important role in soil carbon sequestration

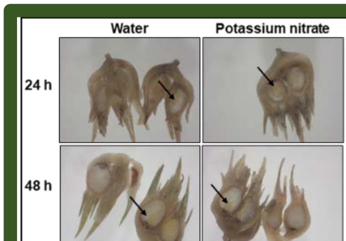
Improving bioenergy and forage plants and production systems for the central U.S.

Wheat, Sorghum, and Forage Research Unit, Lincoln, NE
Project Number: 3042-21000-030-00-D

Lead Scientist: Robert Mitchell
Team Members: Serge Edme, Gautam Sarath

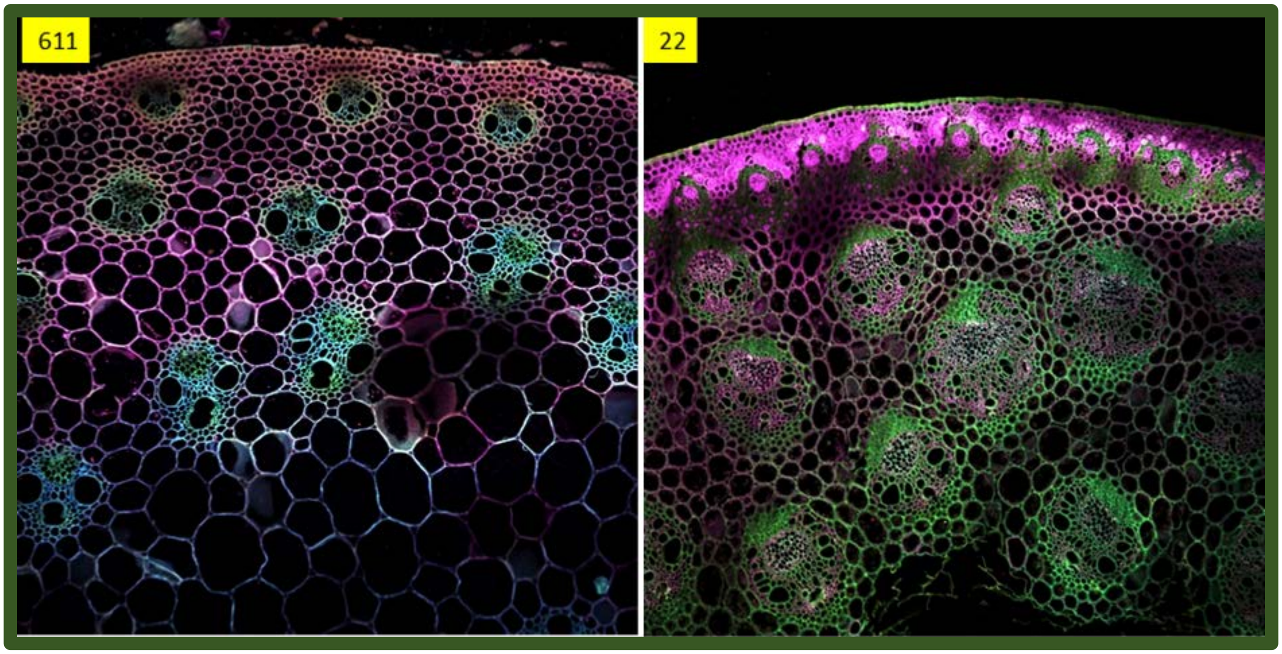
Winter annual cover crops provide variable returns when grazed in spring. Winter wheat, cereal rye, and triticale are important cool-season annual forages and cover crops throughout the Great Plains and Midwest. However, there is little information available that compares the profit from grazing these three cover crops. ARS researchers in Lincoln, Nebraska, and university colleagues compared steer performance in a 3-yr grazing trial by no-till seeding winter wheat, winter rye, and winter triticale into soybean stubble in the autumn, then grazing the following spring. Each pasture was continuously stocked in spring with four crossbred yearling steers for 17, 32, and 28 d in the three grazing years. Spring forage production was variable, but generally, cereal rye had greater growth than either triticale or wheat. No single forage provided superior steer performance across all years. Based on the 3-year average animal gains per acre and $0.60 per pound of animal gain, however, triticale had a 3-year mean net return of $25.15 per acre per year, followed by wheat at $9.13 per acre per year, while cereal rye lost money at -$11.70 per acre per year. As these small grains provide ecosystem services in addition to forage, grazing cover crops could serve as a mechanism for recovering costs and adds additional value to the crop-livestock system. This effort gives livestock producers information to select the most profitable cover crop for eastern Nebraska.

Seed dormancy and germination frequently limit establishment of perennial grasses. Buffalograss seed lots typically have poor germination, largely a result of seed dormancy. Buffalograss seeds, called burs, contain 3 or more potentially germinable caryopses. The mechanisms that control seed dormancy or those that enhance germination in intact buffalograss burs are not known. Germination enhancing treatments developed for switchgrass have shown



Sundancer buffalograss cut in half following treatment with water or potassium nitrate Arrows indicate evidence of increased hydration in seeds treated with nitrate, which also had better germination promise for increasing buffalograss germination. ARS researchers in Lincoln, Nebraska, working with university colleagues, found treating buffalograss seed with potassium nitrate improved water uptake by the burs, which appears to improve germination in buffalograss seed lots.

Conventional breeding can improve switchgrass populations for bioenergy. A switchgrass population, derived from crossing two different types chosen to combine high yield potential and high winter survival, is under population improvement for bioenergy. The lignocellulosic platform requires cultivars to have high biomass yield and



low lignin content to be economically viable. Conventional breeding has brought some changes in the relationships among the three traits that are being measured to improve this population. ARS researchers in Lincoln, Nebraska, have demonstrated that simultaneously selecting for high biomass yield and low lignin content would meet the goals of decreasing lignin content and increasing ethanol yield of the plants. The results indicate that greater gains can be achieved with this population, but that necessitates monitoring the relationships among the biomass yield, lignin content, and ethanol yield in order to ensure their continuous improvement in each switchgrass generation.

NORTH DAKOTA

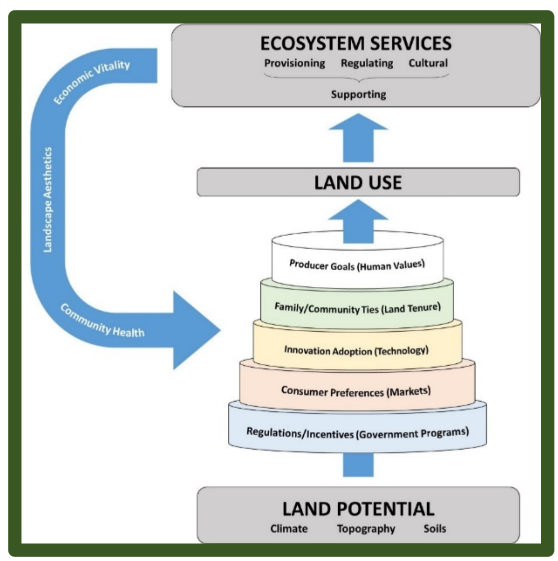
Sustainable Agricultural Systems for the Northern Great Plains

Natural Resource Management Research Unit, Mandan, ND
Project Number: 3064-21660-003-00-D
Lead Scientist: John Hendrickson

Team Members: David Toledo, David Archer, Scott Kronberg, Jonathan Halvorson, Mark Liebig

Sampling depth confounds soil acidification outcomes. Low soil pH can affect herbicide persistence, decrease nutrient availability, and contribute to metal toxicity, all of which can compromise crop production. In the northern Great Plains, surface sampling depths of 0-6″ or 0-8″ are suggested for testing soil pH. Soil acidification, however, is often most pronounced nearer to the soil surface. ARS researchers in Mandan, North Dakota, quantified soil pH change at three depths in two long-term dryland cropping studies and found sampling depth to be an important confounding factor affecting pH outcomes. Significant differences existed between sampling depths for both final soil pH and pH change in both studies. Final pH values were higher (and pH changes smaller) as sampling depth increased. Findings from this evaluation suggest the regionally-recommended sampling depths of up to 8″ may be too deep for early detection of surface acidification. Adoption of surface sampling depths less than 3″ is recommended for testing soil pH in the northern Great Plains.

Aligning land use with land potential. Contemporary agricultural land use is dominated by an emphasis on provisioning services by applying energy-intensive inputs through relatively uniform production systems across variable landscapes. This approach to agricultural land use is not sustainable. Achieving sustainable use of agricultural land should instead focus on the application of innovative management systems that provide multiple ecosystem services on lands with varying inherent qualities. ARS researchers in Mandan, North Dakota, led a group of USDA and university scientists to explore the potential



of integrated agricultural systems (IAS) to improve efficient use of agricultural land. Sustainable deployment of IAS on agricultural land involves placing the 'right enterprise' at the 'right intensity' at the 'right time' on the 'right location', with the inherent attributes of location informing management decisions associated with other variables. Adoption of IAS could result in a transition towards multi-functional agricultural landscapes, improved delivery of multiple ecosystem services, and ultimately, a more sustainable agriculture.

Adaptive nutrient management best course for integrated crop-livestock systems. Efficient use of plant nutrients serves as a defining attribute to concurrently achieve production and environmental goals in integrated crop-livestock systems. Unfortunately, there is a lack of published findings on soil nutrient dynamics for integrated systems, particularly in semiarid regions. To address this need, ARS researchers in Mandan, North Dakota, conducted a study to determine effects of residue and grazing management on soil nitrate and available phosphorus over a 12-year period within an integrated crop-livestock systems experiment. Residue management had no effect on soil nitrate or phosphorus for any year, implying no accumulation of either nutrient under grazing compared to cropping. Similarly, no differences in soil nitrate or phosphorus were observed across grazed sampling zones. Soil nutrients, however, increased or fluctuated greatly over the 12 year period, suggesting a need for adaptive nutrient management. Management interventions targeting nutrient conservation, such as adjusting fertilizer rates in the spring and seeding cover crops in late summer, may improve nutrient use efficiency in integrated crop-livestock systems.

Perennial biofeedstocks improve soil, increase stability. Understanding how perennial herbaceous biofeedstocks alter soil properties, and in turn, how such alterations affect ecosystem services is essential for the development and adoption of improved management practices to promote multifunctional agricultural landscapes. ARS researchers in Mandan, North Dakota, quantified changes to soil properties resulting from different perennial biofeedstocks at five sites in central and western North Dakota over a 5-yr period. Perennial biofeedstocks induced changes in soil properties over the study period, with substantial declines in available phosphorus (P) at sites with high initial P and modest increases in soil organic carbon (SOC) at sites with low initial SOC. Accordingly, results highlighted the value of perennial biofeedstocks to remediate nutrient-laden and/or degraded soils. In contrast, other soil properties changed minimally (electrical conductivity) or not at all (soil pH). Such resistance to change can have important implications for continued soil function, and can confer a period of stability against a backdrop of increased salinity and acidification for rainfed cropping systems in the Northern Great Plains.

Condensed tannins in livestock feed affect manure nutrient excretion. The effects of condensed tannins on N dynamics in ruminants have been a topic of research for some time, but much less work has focused on their impacts on other nutrients in manure. ARS researchers in Mandan, North Dakota, conducted a study to determine if sericea lespedeza (a condensed tannin source) would affect concentrations of nutrients in manure and patterns of total excretion when offered with alfalfa to sheep. With sericea lespedeza additions, average daily manure production increased linearly. Concentrations of several nutrients in manure, total output of these nutrients, and ratios of nutrient outputs to feed inputs were significantly affected by the amount of sericea lespedeza offered in the feed. This study suggests that dietary tannins, found in forages like sericea lespedeza, can alter the concentrations, total excretion rates and throughput efficiency of nutrients in manure. These results may be used to help livestock producers and land managers improve nutrient use efficiency and reduce loss of nutrients to the environment.

Canola-derived jet fuel reduces greenhouse gas emissions and fossil energy demand. Commercial aviation has established goals to reduce greenhouse gas emissions, and renewable fuels have been identified as a way to help meet these goals. Collaborative research including ARS researchers in Mandan, North Dakota, Michigan Technological University, and the U.S. Department of Transportation in Cambridge, Massachusetts, used conducted life cycle assessment using crop simulation modeling and economic analysis for renewable jet fuel produced from canola grown in North Dakota.

Results showed that net greenhouse gas emissions could be reduced by 42-114%, and fossil energy demand could be reduced by 43-133% relative to conventional jet fuel. These results are useful to crop producers, biofuel and aviation industry, and regulatory agencies in identifying fuels and feedstocks with greatest potential for meeting sustainability goals.

Water footprint of rapeseed-derived jet fuel. Rapeseed is a crop that can be used to make renewable jet fuel. However, large-scale biofuel production could affect water supply and quality. In collaborative research including scientists at Michigan Technological University, the U.S. Department of Transportation in Cambridge, Massachusetts, and ARS researchers in Mandan, North Dakota, life cycle water footprint was analyzed for rapeseed jet fuel production scenarios in North Dakota. The analysis included different categories of water use. Results showed that 66-68% of the water footprint is the water used in growing rapeseed and comes from rainfall, and only four percent of the footprint is from surface or groundwater sources. The results are important for policy makers and biofuel industry to understand how producing jet fuel from rapeseed might affect water supply and quality across a broad region.

SOUTH DAKOTA

Soil and Crop Management for Enhanced Soil Health, Resilient Cropping Systems, and Sustainable Agriculture in the Northern Great Plains

Integrated Cropping Systems Research Unit, Brookings, SD
Project Number: 3080-12620-005-00-D
Lead Scientist: Shannon Osborne
Team Members: Louis Hesler, Michael Lehman, Sharon Papiernik, Walter Riedell

Reduce nitrogen loss, increase soil carbon and crop yields by crop diversification. Improving crop production practices will increase producer profit and minimize any negative off-farm impacts. Diversification of crop rotations is a fundamental tactic that can produce substantial producer and societal benefits. Using long-term research plots established in the northern Corn Belt, ARS researchers in Brookings, South Dakota, evaluated a two-year conventional corn-soybean rotation in comparison to a four-year corn-field peas-winter wheat-corn rotation. Both cropping rotations were conducted under no-till conditions. Compared to the two-year rotation, the four-year rotation increased soybean yield by 22%, decreased by 24% the loss of nitrogen through atmospheric emissions of nitrous oxide, and increased the rate and depth of soil organic carbon accumulation. Results demonstrate that crop production systems can be adjusted to achieve higher yields and retain more nutrients and carbon in soil compared to existing practices. It is critical to have demonstrated solutions that apply to regionally-specific conditions and management practices so that producers can respond to market and policy influences. Improving the efficiency of cropping systems improves producer profitability, reduces soil loss and degradation, and supports public interests by improving water and air quality.

Arbuscular mycorrhizal fungi not inhibited by seed-applied fungicides. Fungicidal seed coatings have become standard on commodity crop seed to control pathogenic fungi prior to germination. However, seed-applied fungicidal formulations containing multiple systemic ingredients could impact non-target soil fungi such as obligate plant symbiotic arbuscular mycorrhizal (AM) fungi. Symbiotic AM fungi commonly supply nutrients (particularly phosphorus), water, and pest/pathogen resistance to their plant hosts. ARS researchers in Brookings, South Dakota, evaluated the potential for contemporary, seed-applied fungicidal formulations to inhibit AM fungal root colonization or alter plant nutrient content of corn, soybean, and oat. Commercial fungicidal seed coatings applied at their labeled rate did not significantly reduce root colonization by AM fungi or phosphorus content of any plant compared to the untreated control. Plant genotype (hybrid or variety) significantly affected AM fungal root colonization and plant nutrient content for the crops studied. The potential for non-target effects of seed-applied fungicides has been an ongoing concern of producers who are interested in promoting soil biological diversity and function. These results indicate that other factors may be more important in determining the beneficial soil fungi population.

Crop diversity: a recipe for productive and sustainable agriculture. Highly specialized cash-grain production systems based upon corn-soybean rotations under tilled soil management are common in the northwestern U.S. Corn Belt. This rotation is expensive to maintain in terms of agricultural inputs needed such as pesticides and fertilizer cost. A long-term study, initiated in 1997 by ARS researchers in Brookings, South Dakota, was conducted to determine if diversification of this ubiquitous corn-soybean rotation would affect soil characteristics and crop productivity under no-till soil management. They determined the effects of a 2-year

rotation (corn-soybean), 3-year rotation (corn-soybean-spring wheat), and 5-year rotation (corn-soybean-oat/pea hay-alfalfa-alfalfa) on soil bulk density, soil carbon sequestration, and residual soil nitrate-N as well as on corn and soybean yield productivity and seed protein. They found that diversification of the corn-soybean rotation with oat/pea and alfalfa hay made soils less dense, increased soil carbon, increased soil nitrogen available to corn and soybean phases, and increased corn and soybean grain yield as well as seed protein. In contrast, diversification with wheat only increased corn and soybean grain yield. Findings were communicated to producers, crop consultants and scientist through various outreach activities. These data elucidate the complex relationships between soil attributes, crop rotations, and crop yield that help provide a basis for improving the productivity and sustainability of agricultural systems to meet the demand for increased productivity while maintaining or improving the soil resource.

Fighting soil salinity in the northwest U.S. corn belt. Soil salinity is expanding in the east central Dakotas, and limiting crop productivity. Because of poor surface drainage and saline parent materials, soil water deposited during wet years moves up from deep in the soil profile during dry periods, where it evaporates and leaves behind high concentrations of salt. As salt concentrations build up, farmers can no longer use their land to plant salt-susceptible crops important to the economic sustainability of the region. In an effort to fight increasing salinity, ARS researchers in Brookings, South Dakota, collaborated with soil health specialists at the USDA Natural Resources Conservation Service to investigate the use of perennial grasses to mitigate soil salinity. They found that cultivation of salt tolerant grasses reduced soil salinity and helped remediate the soil. Findings were communicated to producers, crop consultants and scientist through various outreach activities.

TEXAS

Precipitation and Irrigation Management to Optimize Profits from Crop Production

Soil and Water Management Research, Bushland, TX

Project Number: 3090-13000-015-00-D
Lead Scientist: David Brauer
Team Members: Roland Baumhardt, Paul Colaizzi, Steven Evett, Susan O'Shaughnessy, Robert Schwartz, Gary Marek

Irrigation requirements for rotations defined for Texas High Plains. Groundwater resources on the Southern High Plains are finite and becoming increasingly scarce. Crop water use is the major use of rain and irrigation water. However, crop rotation strategies that minimize groundwater use may help to extend these resources. Thus, researchers in Bushland, Texas, and Texas A&M AgriLife Research used the Soil Water Assessment Tool (SWAT) model and long-term weather data to characterize simulated irrigation requirements of several crop rotations used in the Texas High Plains. Results may serve as a decision tool for producers considering alternate crop rotation strategies by providing irrigation requirements for comparison to known irrigation capacities.

Forecast of an El Nino predicts higher wheat yields for the Texas High Plains. As water for irrigation from the Ogallala Aquifer declines, dryland farming will become a more prevalent land use practice. Adapting practices to exploit long term climate forecasts may enable farmers to realize higher yields. Equatorial Pacific sea surface temperatures cause predictable El Nino and La Nina weather patterns in much of North America. However, crop management protocols that take into account a forecast for either El Nino or La Nina have not been developed. ARS researchers in Bushland and Lubbock, Texas, compared the effects of El Nino and La Nina periods on crop growth and yield in a dryland wheat-sorghum-fallow rotation over 58 years. Wheat growing-season rain and grain yields were greater for El Nino phase years than La Nina phase years. These results are of interest to

farmers and crop consultants as an aid to making strategic decisions regarding future crop practices.

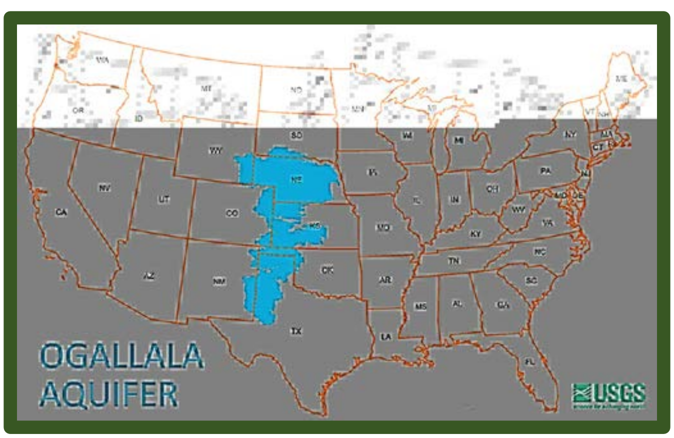
Method to determine leaf canopy size from simple measurements. Leaf area index (LAI), plant leaf area per unit ground area, is a very important indicator of the productivity of the agricultural systems, but is difficult to measure directly. LAI can be estimated indirectly using other plant measurements, such as individual leaf length and width, but such data are also often impractical to obtain. Therefore, ARS researchers in Bushland, Texas, developed a new method to estimate LAI for row crops. The method uses growing degree days, canopy height, and plant population, which are easily obtained and more widely available. The scientists tested the method using existing LAI measurements of corn, cotton, grain sorghum, and soybean and the method could estimate LAI with good accuracy. The method will make LAI estimates more practical and widely available compared with previous methods, and this will enhance the usefulness of large agricultural and ecological datasets.

Wireless plant leaf temperature measurements makes irrigation scheduling easier. The freshwater resources available for agriculture are diminishing due to reduced supplies and competition for other uses. Freshwater resources can be used more efficiently in agriculture by knowing when to irrigate crops. One method that can quickly tell farmers when to irrigate is calculation of a crop water stress index from plant leaf temperature measurements. However, measuring plant leaf temperature in entire fields was not practical until ARS researchers in Bushland, Texas, developed a wireless sensor system that measures plant leaf temperature over entire fields. The system was mounted to conventional and variable rate center pivot irrigation sprinklers. Results showed that irrigation timing and amount determined from the crop water stress index using the sensor system could be a viable alternative to estimating crop water use by soil water measurements. Because over half of the irrigated area in the U.S. is now by center pivot, estimates of crop water use by sensors aboard center pivots will provide an unprecedented opportunity to conserve water.

Popular crop model overpredicts corn growth under limited water. Water scarcity due to drought and groundwater depletion has led to an increased number of modeling studies aimed at evaluating crop response to limited irrigation. The Decision Support System for Agrotechnology Transfer (DSSAT) is a widely used crop growth model. However, the ability of DSSAT to represent crop response and water balance under limited irrigation is not well studied. Therefore, ARS researchers in Bushland, Texas, and Texas A&M AgriLife compared simulated and measured plant growth values for corn grown in the Texas Panhandle under full and limited irrigation. Results showed that DSSAT overestimated corn growth, yield, and crop water use (evapotranspiration) under limited irrigation conditions when calibrated using collocated fully irrigated treatments. These results are of interest to agronomists, plant physiologists, and crop modelers because they demonstrated the weakness of plant stress algorithms in the current model to simulate corn growth under less than ideal growing conditions.

Soil water assessment tool does not mimic current irrigation practices. Water scarcity due to drought and groundwater depletion has led to an increased emphasis on irrigation strategies for extending limited water resources. Models are commonly used to assess the impacts of such strategies. The Soil and Water Assessment Tool (SWAT), a widely used hydrologic model, is increasingly being used to evaluate the impacts of irrigation strategies at both field and watershed scales. However, concerns about the ability of the auto-irrigate function in SWAT to simulate actual irrigation practices have tempered results. ARS researchers in Bushland, Texas, along with scientists from Texas A&M AgriLife compared simulated irrigation, crop water use (ET), plant growth, and yield to measured values for crops grown in the Texas High Plains. Results showed that the auto-irrigate function was unable to represent irrigation practices of the region, prompting the need for revision of the algorithm. Alternative algorithms have demonstrated improved simulation of regional irrigation practices. These results are of interest to SWAT users, users of other models, and water policy makers using such information.

Effectiveness of water conservation policies affected by discount rates, and crop prices. Agriculture plays a vital role in the growth and development of the High Plains region of the United States. With the development and adoption of irrigation technology, this region was transformed into one of the most agriculturally productive regions in the world. The primary source of irrigation water in this region is the Ogallala Aquifer. Currently, water from the aquifer is being used at a much faster rate than natural recharge can occur, resulting in a high rate of depletion from this finite resource. However,



depletion of scarce water resources will have a significant economic impact on the long-term sustainability of the region. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from West Texas A&M University and Kansas State University in the Ogallala Aquifer Program to evaluate the impact alternative prices and discount rates on groundwater policy recommendations. As indicated by results of this study, alternative prices, costs, and discount rates utilized in the study have an effect on policy effectiveness. These results are of interest to water policy makers and demonstrate the importance of economic assumptions in the outcome.

Future value of groundwater too low to prevent its current use. Irrigation water from the Ogallala Aquifer has had an influential role on the Texas High Plain in making it an agriculturally significant region. However, withdrawals for irrigation have greatly exceeded recharge, resulting in a decreasing water resource. ARS researchers in Bushland, Texas, cooperated with scientists from Texas Tech University in the Ogallala Aquifer Program to attempt to quantify the shadow price of an additional inch of groundwater resource left in situ for the Southern Ogallala Aquifer. We arrived at a marginal user cost for an additional acre-inch of water which is relatively low. Because this cost is so low, farmers are unlikely to conserve water based on economic considerations. These results are of interest to water policymakers and indicate that value of groundwater left in the aquifer is only slightly different from its value for present withdrawals.

Protein that helps confer salt tolerance identified. As water is removed from the Ogallala Aquifer there are concerns that the quality of the remaining water will be degraded. In general, crops are not very tolerant of water with poor quality that is high salt content. Crops that are tolerant of high salt maybe needed for the Southern Ogallala Aquifer region. Unfortunately, there are multiple avenues to breed crops for greater salt tolerance and few approaches have been attempted. Scientists have previously associated a specific plant protein with tolerance to salt. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from Texas Tech University and Zhejiang Academy of Agricultural Sciences (China) in the Ogallala Aquifer Program to investigate the role of root growth under salt stress. Loss of this protein through mutations decreased salt tolerance while over production of this protein improved salt tolerance. These data indicate that this specific protein affects salt tolerance. These results are of interest to plant physiologists, plant molecular biologists and plant breeders.

Switching to highly efficient irrigation systems requires increases in yields to recover cost. Crop yields have not decreased as water availability for irrigation from the Ogallala Aquifer has declined because of advancements in irrigation technology. However, producers can be reluctant to convert to a more efficient irrigation system when the initial investment costs are high. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from West Texas A&M University and Texas A&M AgriLife Research and Extension Service in the Ogallala Aquifer Program to examine the economic feasibility of

replacing low energy precision application (LEPA) center pivot sprinkler with subsurface drip irrigation (SDI). The increase in water use efficiency from LEPA to SDI was sometimes inconsistent, and depended on the crop grown and the amount of irrigation water applied. Further analyses demonstrated that a timely return on investment from switching from LEPA to SDI was only possible with high value crops that had an increase in yield after the conversion. Corn, for example, is a typically grown row crop that has an inconsistent yield response to LEPA vs. SDI and is not considered a high value crop. These results are of interest to water policy makers, especially when making decisions regarding cost share for water conversing irrigation equipment.

Use of animal waste on crop land requires balancing applications with crop requirements. Application of cattle manure and swine effluent to cropland builds nutrient pools, affects soil quality, and increases crop productivity. However, application of animal waste in excess of crop nutrient requirements may lead to build up of soil nutrients that may have adverse environmental effects. ARS researchers in Bushland, Texas, cooperated with scientists from Kansas State University in the Ogallala Aquifer Program to evaluate the rate of change in soil nutrient concentration and soil chemical properties in response cattle manure and swine effluent applications over a ten year period. A significant build up in soil nutrients of phosphorus and nitrate occurred when cattle and swine nutrient applications were supplied to meet or exceed the crop's nitrogen requirement. These results indicate that farmers need to balance nutrient additions to crop requirements to avoid building up soil levels of these nutrients.

Improvements to beef slaughter procedure saves water. Water availability from the Ogallala Aquifer is declining. Beef slaughter is water intensive due to stringent food safety requirements. However, water use by slaughter facilities are high value use. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from West

Texas A&M University in the Ogallala Aquifer Program to conduct a study at a commercial beef processor to demonstrate water conservation by modifying the mechanical head wash. The modified mechanical washer cleaned beef heads as well as the standard washer but used 48% less water. These results are of interest to beef slaughter plants using water from the aquifer.

New design practices for efficient subsurface drip irrigation (SDI). As water availability from the Ogallala Aquifer for irrigation decreases, farmers are looking at installing the most water efficient irrigation systems. Yields per unit of applied water tends to be highest with SDI compared to other irrigation systems. However, SDI is a

relatively new irrigation technology and design features are still evolving. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from Kansas State University in the Ogallala Aquifer Program to examine the applicability of fluid equations to the design of flushlines. The authors recommend that these modified equations be used with a standard fluid model to ensure reliability of improved flushline design for SDI systems.

Wheat does best with 4 inches of irrigation. Water availability from the Ogallala Aquifer for irrigation is decreasing, the occurrence of limited irrigation will increase on the Southern High Plains. Increasing irrigated wheat yields is important to the profitability of limited-irrigation cropping systems in the region. ARS researchers in Bushland, Texas, cooperated with scientists from Kansas State University in the Ogallala Aquifer Program to examine the response of various wheat varieties to limited irrigation. Results indicated that, on average, an irrigation allocation of 4 inches increased wheat yield by 14% to 46%

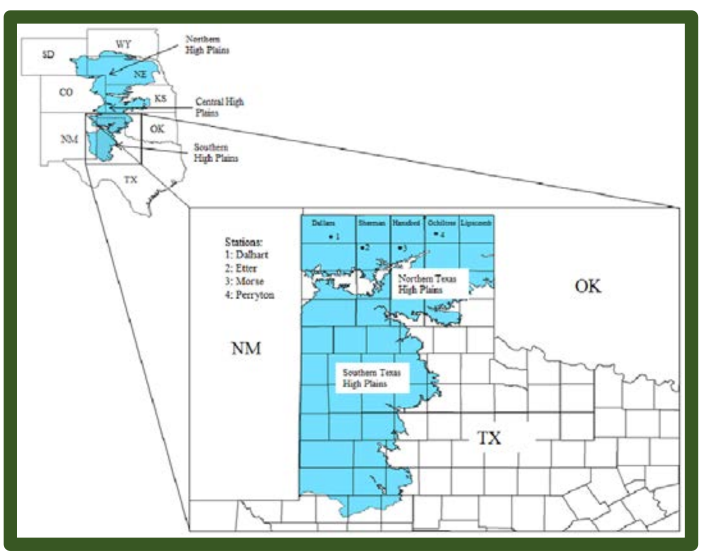
compared to rainfed production. Application of an additional 4 inches of irrigation did not improve wheat yield substantially. Applications at booting and heading resulted in the highest yields. This study demonstrates that limited irrigation targeted at sensitive growth stages could enhance wheat yields and improve water productivity of water-limited cropping systems, and are of interest to farmers.

Developing education programs for water management. Natural resource management and education, including those related to groundwater, must account for both the natural and human components of a very complex interactive system. However, examples of such interdisciplinary approaches are rare, and therefore guidelines for successful natural resource education programs are poorly defined. ARS researchers in Bushland, Texas, cooperated with scientists from Kansas State University, Auburn University and University of Minnesota in the Ogallala Aquifer Program to develop a graduate seminar on water management. While the seminar was successful in terms of educating students on complexity of water management, several challenges remain when implementing such courses. These challenges include not only the organization and assessment of course deliverables, but also fitting such courses into the administrative structure of the university when represented disciplines are located in several colleges across campus. These results are of interest to other universities developing similar courses.

Late planted sorghum best for irrigation water efficiency. Many wells on the Southern High Plains drilled into the Ogallala Aquifer can no longer meet full crop water requirements due to declines in water levels. However, these sites are capable of contributing to the regional agricultural economy under appropriate management protocols. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from Kansas State University in the Ogallala Aquifer Program to conduct a study to determine optimum limited irrigation strategies for grain sorghum with varying planting dates. Highest grain yields were achieved with a late planting date in a wet season. Late planting was associated with lower irrigation requirements. Fluctuations in grain sorghum prices had a substantial impact on economic water productivity. Overall planting grain sorghum under optimum conditions combined with deficit irrigation improved water productivity. However the presence of sugar cane aphids may negate the advantages of late planted sorghum.

Increases in crop yields will help offset decreased irrigation water availability. The continued decline in the availability of water from the Ogallala Aquifer in the Texas Panhandle has led to an increased interest in conservation practices to extend the life of the aquifer and sustain rural economies. However, water policy makers need information on the effectiveness of conservation practices to conserve water in the aquifer while simultaneously considering the economic costs to producers. ARS researchers in Bushland, Texas, cooperated with scientists from West Texas A&M University, the University of Tennessee at Martin, Clarendon College and Fatima Jinnah Women University (Rawalpindi, Pakistan) in the Ogallala Aquifer Program to evaluate the effectiveness of five policies in terms of changes in the saturated thickness, crop mix, water use per acre, and the net present value of farm profits over a 60-year planning horizon. Results indicate that the policy scenarios of biotechnology adoption (germplasm with 3% annual increase in yield) and a water use restriction will conserve the most water. In terms of economic returns, the biotechnology adoption policy by far provided the greatest benefit to producers. These comparisons will aid policy makers in determining the most effective strategy to conserve water while simultaneously considering the economic costs to producers. In addition, the results of this study can be applied to other areas facing similar conditions, either currently or in the future, throughout the Texas Panhandle.

Possibility of groundwater restrictions may increase short-term aquifer depletion. Concerns about the high rate of depletion of the Ogallala Aquifer in the Southern High Plains of Texas (Texas High Plains) in recent years have led to the enactment of policies designed to slow down water extraction and increase the usable life of the aquifer. However, policy implementation has not been uniform across the aquifer, leaving some farmers in portions of the aquifer with no effective groundwater extraction restrictions only a short distance away from areas where farmers face regulatory limits. Therefore, ARS researchers in Bushland, Texas, cooperated with scientists from Texas Tech University in the Ogallala Aquifer Program to investigate the effects of policy implementation uncertainty on the extraction of groundwater. Producers, in their concern about the implementation of policies to slow down groundwater extraction, increase their use of water in the short-run in order to maximize profits before groundwater use restriction policies are enforced. These results are of interest to water policy makers.

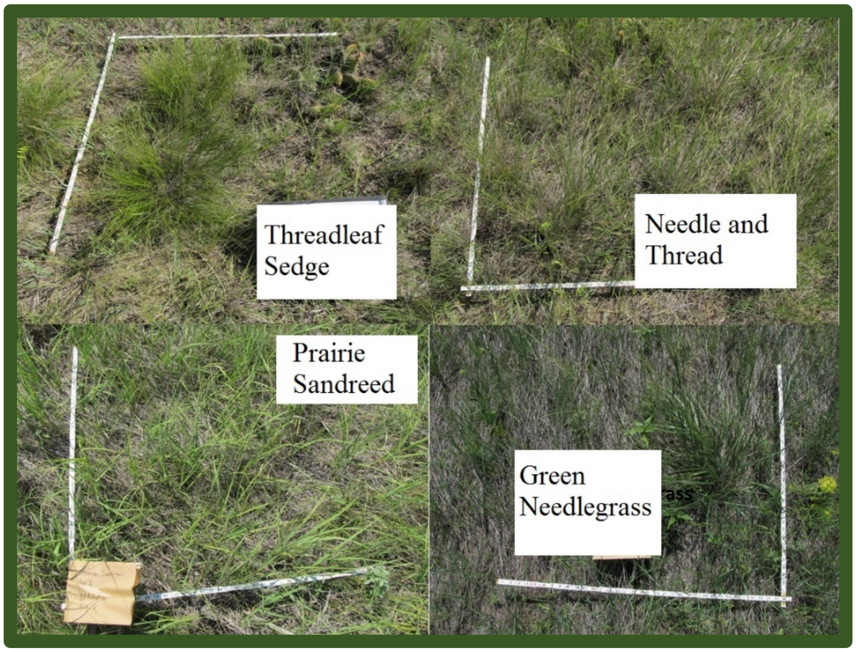


Development and Evaluation of Sustainable Crop and Grassland Production Systems

Grassland Soil and Water Research Laboratory, Temple, TX
Project Number: 3098-11220-008-00-D
Lead Scientist: Philip Fay
Team Members: Harold Collins, Richard Haney, Wayne Polley, James Kiniry, Douglas Smith

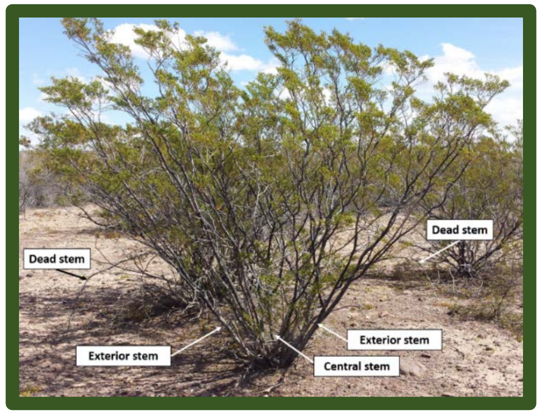
Accelerated growth in an exotic invasive grass suppresses native grasses. Biological invasions by exotic plant species can cause losses of native species and economic losses in agricultural ecosystems. The plant characteristics conferring invasiveness in exotic species is unclear in the case of invasive warm-season grasses that invade North American grasslands dominated by warm season native grasses such as big bluestem, switchgrass, and little bluestem. Understanding how these widespread and abundant native warm season grasses differ from invasive warm season grasses such as Johnsongrass (Sorghum halepense) is crucial to designing effective management strategies to minimize harmful impacts of exotic grasses on natural and agricultural ecosystems. ARS researchers in Temple, Texas, showed that over a full growing season, Johnsongrass increased its size advantage over big bluestem, little bluestem and switchgrass by up to 70:1, and suppressed the nitrogen content of native grasses, while maintaining high total nitrogen uptake. The initial early size advantage of Johnsongrass is thus maintained over a full growing season, and depends on its ability to establish a size advantage within days of germination and to disproportionately acquire nitrogen. Native grasses could be favored against Johnsongrass by management that stimulates earlier native grass growth in spring.

Vegetation indicators of stability in grassland plant productivity. Improving our capacity to manage grassland ecosystems is a priority in a rapidly changing world. One technique to do so is to identify readily-measurable properties of grassland vegetation as indicators of management outcomes. ARS researchers in Temple, Texas, evaluated two vegetation properties, species diversity and a trait representing leaf thickness (community-averaged values of specific leaf area) as predictors of the year to year stability of plant productivity in individual communities and in across multiple adjacent communities. Across adjacent communities, when species had thinner leaves they were more stable in productivity. Communities for which leaf thickness varied from year to year were less influenced by precipitation variability. Conversely, increasing species diversity destabilized productivity because highly stable dominant species became less abundant. Leaf thickness variation can be a useful tool to estimate community stability and contributing mechanisms.



Growth parameters for rangeland grasses. Rangeland grasses in the arid western U.S. must grow quickly, set seed, and lose their green leaves in a relatively short timeframe in order to survive and reproduce when the limited soil moisture is available. In addition, rangeland management in arid sites can benefit from computer models to optimize grazing intensity and duration and for assessing impacts of invasive species and/or climate change. ARS researchers in Temple, Texas, derived the variables needed to simulate growth of three common cool season grasses and one warm season grass in Montana with the ALMANAC computer model. These growth variables were then used with the computer model to simulate three typical range sites near Miles City, Montana. Model variables, such as the amount of plant growth per unit light intercepted and potential leaf area cover, showed expected trends with the four grasses. Simulations showed reasonable agreement with published grass yields for normal years, wet years, and dry years. Thus, this computer model and the growth variables such as those described herein will be valuable for assessing various management scenarios and climate variables in these types of low rainfall, western U.S. range sites.

Controls on growth and development of Creosote bush in arid rangelands. Creosote bush is a desert evergreen, perennial shrub which dominates arid rangelands in southwestern Texas, U.S. Controlling creosote bush in desert rangelands is important because, as it increases in density, perennial grass production is reduced. ARS researchers in Temple, Texas, investigated associations among several plant and environmental characteristics (e.g., slope, elevation, and water runoff index) that affect distribution, abundance, and production of creosote bush. A range of morphological traits were investigated at several southwestern Texas sites, and growth ring and growth rate were also measured. Creosote bushes with a wide range of ages (3 - 18 years) occurred mostly in pure stands, and sometimes in small groups, in all study sites. Two groups were categorized based on crown size: smaller, conical-shaped shrubs and larger, hemispherical-shaped shrubs. Creosote productivity was positively associated with the fraction of hemispherical-shaped shrubs in the population. Wetter sites supported more of the larger, hemispherical class of shrubs, resulting in higher production. The total density of creosote bush decreased as land slope increased. This may be due to high water limitation in steeper slopes. The results of this study will improve understanding of the most important factors that affect creosote bush production, which will help to develop management strategies for desert rangelands.



Careful management can greatly decrease the water quality impact of phosphorus fertilizers. Agricultural nutrient losses have been identified as contributing to water quality degradation. Phosphorus fertilizers commonly are broadcast on the soil surface of row crop fields in the fall or spring, prior to crop planting. This leaves the fertilizer highly vulnerable to being lost during the first rainstorm. The form, rate and placement of fertilizers may be able to mitigate some of the nutrient losses from agricultural fields. ARS researchers in Temple, Texas, investigated the role of fertilizer source, placement and rate on phosphorus loss via runoff. Highly soluble dry fertilizers (e.g., monoammonium phosphate and diammonium phosphate) applied to the soil surface resulted in high concentrations of phosphorus in runoff water, and lost as much as 19% of the phosphorus that was applied. Liquid fertilizer (polyphosphate) resulted in 98% less phosphorus lost in runoff, likely because the liquid fertilizer is able to infiltrate the soil. Banding fertilizer only ½ inch below the soil surface resulted in as much as a 98% decrease in phosphorus runoff compared to the same fertilizer that was surface broadcast. These results provide guidance to farmers and resource managers on fertilizer management techniques that can be easily incorporated to most row crop farming operations to reduce the environmental footprint of agriculture.

Intercropping switchgrass and hybrid poplar can reduce greenhouse gas emissions. Shifts from crop production to biomass feedstock production will change agroecosystem services related to water use, carbon storage, and greenhouse gas emissions, with direct consequences on air, water, and soil quality. Commercial hybrid poplar plantations in the Pacific Northwest managed for high-value timber production use low planting densities, leaving an open understory suitable for production of bioenergy feedstocks. ARS researchers in Temple, Texas, measured greenhouse gas emissions in irrigated

plantings of hybrid poplar intercropped with 'Kanlow' switchgrass. Over four years of production, losses of two potent greenhouse gases, carbon dioxide and nitrous oxide, increased following the application of nitrogen fertilizer. Nitrous oxide emission factors were greatest in fertilized treatments, averaging 1.3% of the applied nitrogen after four years of cropping. Contributions of greenhouse gas emissions to the total Global Warming Potentials of the poplar/switchgrass intercrop system were offset by the carbon fixed in crop biomass, resulting in no net change in global warm potential for monoculture poplar. In contrast, poplar/switchgrass intercrop and switchgrass monocultures sequestered significant amounts of carbon dioxide, and reduced the net Global Warming Potential over 4 years. Intercropping switchgrass with hybrid poplar was shown to be a viable mitigation strategy to counter rising Global Warming Potentials.

Resilient Management Systems and Decision Support Tools to Optimize Agricultural Production and Watershed Responses from Field to National Scale

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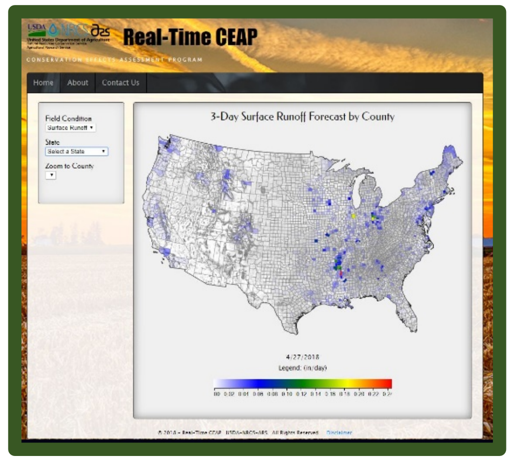
Second generation Conservation Effects Assessment Project initiated. The successful completion of the Conservation Effects Assessment Project (CEAP) cropland assessment highlighted several improvements that are needed in future assessments. Spatial resolution at the watershed scale requires refinement to accurately simulate spatial rainfall variability and to simulate the complete sediment budget including gullies and first order tributaries. This is critical to model legacy sediments and ensure realistic scenario analysis. In order to downscale CEAP, the Soil and Water Assessment Tool (SWAT) model was restructured by ARS researchers in Temple, Texas. The routing structure was redesigned into an object based approach that gives more flexibility in connecting watershed objects (ie: fields, channels, reservoirs, aquifers, etc.). We can now simulate the entire sediment budget for the U.S. including gullies, small tributaries and higher order channels. Drainage and irrigation systems can be modeled more realistically as well as watersheds that do not have

main channels such as playa lakes, non-draining lakes, and wetlands. The climate data was downscaled and multiple year land use data have been combined in a Geographic Information System (GIS) to identify primary crop rotation patterns in the U.S. These data are being used to identify appropriate crop operation templates to use in SWAT. Point sources, reservoir, and atmospheric deposition data were all downscaled and restructured. The National Hydrography Dataset has been analyzed to provide connectivity information for use in SWAT. These data will facilitate the simulation of smaller streams, ponds and flood control structures which are critical sediment and nutrient sinks in many regions. These new capabilities will ensure that CEAP provides scientifically-sound conservation policy.

Data and methods to support advanced conservation and farm management decision support tools developed. Watershed models are useful tools to inform conservation policy, but are too complex and slow to drive real time decision support tools. Model simulation can be performed ahead of time in some cases. The Real-Time Conservation Effects Assessment Project (CEAP) demonstration prototype was recently developed by ARS researchers in Temple, Texas, to help producers make better pesticide/fertilizer application decisions by using Soil and Water Assessment Tool (SWAT) to predict future runoff based on short term forecasts. A web application, grid based national SWAT model, and weather forecast processor has been developed to support this effort. Real-Time CEAP requires only one simulation per day to remain current as weather is the only input variable. More complex decision support



tools may require that every conceivable combination of factors that a decision maker may face could require advanced simulation, a daunting computational problem. A software framework has been developed to configure and execute millions of model simulations in advance on the Temple, Texas, computing cluster, and later "mining" these data to address a specific inquiry using the export coefficient concept. National datasets developed in part for CEAP II have been incorporated in recent testing. These published data include: crop management schedules, soils, station based climate, and conservation practice distributions derived from Google imagery. A test dataset of 100 million simulations was recently developed to predict the effectiveness of various conservation practices by eco-region. Similar datasets with greater resolution will be developed as additional CEAP II datasets become available. Eventually these data will be used to drive web-based tools to estimate the effect of conservation practices and land use change.

Database updated to include crucial nutrient loss pathway. The "Measured Annual Nutrient loads from Agricultural Environments" (MANGE) database has been recognized since 2006 as a resource for information on nutrient losses from agricultural landscapes. However, early versions of this database only contained information on surface runoff pathways. This database was updated by ARS researchers in Temple, Texas, to include additional resources for agricultural and forest landscapes, and now includes more than 90 studies with subsurface tile drainage nutrient loss data. The additional data makes this one of the most robust databases in the world in terms of nutrient fate and transport of nutrient losses from agricultural and forested landscapes.