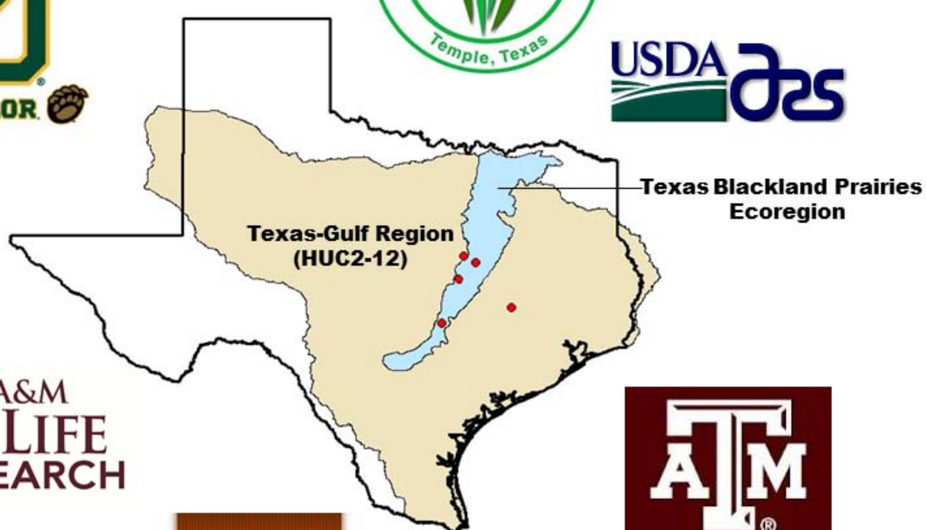
Proposal for Candidacy in the
ARS Long-Term Agro-Ecosystem Research Network

Texas Gulf Research Partnership

USDA-ARS Grassland, Soil and Water Research Laboratory
USDA-ARS Riesel Watersheds
Baylor University, Department of Geology
Texas A&M University, Department of Soil and Crop Sciences
Texas A&M AgriLife Blackland Research and Extension Center
Texas A&M Spatial Sciences Laboratory
USDA-ARS Southern Regional Biofuel Center
Baylor University, Department of Environmental Science
University of Texas at Austin, Department of Geological Sciences



EXECUTIVE SUMMARY

The Texas Gulf Research Partnership (TGRP) is a well-justified candidate for participation in the USDA-ARS Long-Term Agro-ecosystem Research (LTAR) network because of our ability and commitment to conduct integrated research necessary for sustainable agro-ecosystem management. **Our vision is to build on a longstanding history of research collaboration among world-renowned scientists and become a key contributor to the LTAR network by:**

- **contributing legacy data sets and utilizing state-of-the-art scientific infrastructure that facilitate spatial and temporal analysis of interactions in and between complex agro-ecosystems.**
- **developing and implementing innovative management systems to better manage, conserve, protect, and allocate the nation's natural resources in agro-ecosystems and to enhance ecosystem sustainability and services such as air quality, soil health, water quality, agricultural productivity, on-farm profitability, and biodiversity.**
- **providing basic and applied research, new technologies, and data necessary to resolve competing demands and needs of local, State, Federal, and University partners.**
- **working with LTAR partners to establish shared research objectives to maximize LTAR's ability to "scale up" to address regional and national issues and to facilitate cross-site syntheses, allowing theories to be developed and results applied across gradients of climate change, management intensity, and production diversity.**

The ability of the Texas Gulf Research Partnership (TGRP) to accomplish this vision is supported by:

- ***unquestioned scientific productivity*** - The TGRP has an impressive record of multidisciplinary research producing process-based understanding of agricultural management alternatives, applied hydrology and water quality, watershed/agro-ecosystem modeling, carbon dynamics and global change impacts. These long-term efforts along with more recent research on air quality and impacts of bioenergy production address agro-ecosystem effects at multiple spatial scales from field to watershed to national.
- ***state-of-the art scientific infrastructure*** - This infrastructure includes: the Riesel Watersheds, an 340 ha outdoor hydrologic laboratory and nested watershed network designated as a Historical Landmark of Agricultural and Biological Engineering; USDA-ARS Grassland, Soil and Water Research Laboratory and its unique Lysimeter CO_2 Gradient (LYCOG) and Long-Term Biomass Experiment and Nutrient Network infrastructure; USDA-ARS Southern Regional Biofuel Center; and Texas A&M AgriLife Blackland Research and Extension Center.
- ***rich, publically-available data record*** - The TGRP has produced a massive legacy data set with more than 3600 site-years of precipitation, surface runoff, lateral subsurface flow, and soil loss data in addition to 75 years of land management data for the Riesel Watersheds and 100 years of weather data from the USDA-ARS Grassland, Soil and Water Research Laboratory and Texas A&M AgriLife Blackland Research and Extension Center (**www.ars.usda.gov/spa/hydro-data**). In addition, seven years of plant production, soil water and respiration, and environmental data from the LYCOG experiment are available on request to researchers from other institutions.
- ***critical geographic coverage*** - The TGRP provides critical coverage of the Texas-Gulf HUC2-12 basin, a region characterized by rapid population and commercial growth and extensive ongoing land use/cover change. The Texas Gulf has 3 of the 10 largest U.S. cities and 4 of the top 10 fastest growing cities (Forbes, 2012). The TGRP also provides critical coverage for the Texas Blackland Prairies ecoregion, unique because of its socio-economic dependence on agriculture, rapid urbanization, and Houston Black clay soils recognized worldwide as the classic Vertisol.

- ***well-established partnerships*** with local agricultural producers, agricultural interest groups, numerous state and federal agencies, and universities (including Baylor Univ., Brigham Young Univ., Duke Univ., Iowa State Univ., Texas A&M Univ., Univ. of Texas, Texas State Univ.) are longstanding, strong, and mutually beneficial.
- ***institutional commitment*** - USDA-ARS and its TGRP partner institutions have a proven record and a 75 year commitment of research to develop sustainable agro-ecosystems and are leading advocates of a federally-supported national watershed/agro-ecosystem network.

PRODUCTIVITY AND PROCESS-BASED UNDERSTANDING

The TGRP is comprised of basic and applied scientists from USDA-ARS Grassland, Soil and Water Research Laboratory and Southern Regional Biofuel Center; Baylor Univ. Department of Geology and Department of Environmental Science; Texas A&M Univ. Department of Soil and Crop Sciences, Spatial Sciences Laboratory, and Blackland Research and Extension Center; and Univ. of Texas at Austin Department of Geological Sciences. During its 75 year history, this multidisciplinary research partnership has established a proven, longstanding record of scientific productivity and is committed to continue this record. Our researchers continue to formulate and provide critical process-based understanding of agro-ecosystems through research on agricultural management alternatives, applied hydrology and water quality, watershed/agro-ecosystem modeling, carbon dynamics and global change impacts, air quality, and agro-ecosystem impacts of bioenergy production (discussed subsequently, pages 2-8).

Much of the current research by TGRP scientist is conducted in response to requests from stakeholders, elected officials, and partner agencies. These partner agencies include state agencies [e.g., Texas State Soil and Water Conservation Board (TSSWCB), Texas Commission on Environmental Quality (TCEQ), Texas Water Resources Institute (TWRI), Texas Forest Service, and others] and federal agencies [e.g., Environmental Protection Agency (EPA), United State Geological Survey (USGS), USDA Natural Resources Conservation Service (NRCS), Office of Naval Research (ONR), and others]. An integral component in our vision statement is maintaining research capacity to provide science, technology, and data necessary to resolve competing demands and needs of stakeholders and universities, government, and industry that rely on sound strategies to manage, conserve, protect, and allocate the nation's natural resources in agro-ecosystems. Recent requests have been made by TSSWCB, Texas Pork Producers, Department of Defense Office of Naval Research, EPA, Secretary of Agriculture, USDA-NRCS, among others. This responsive component of our overall research program is possible through institutional commitment to maintain and support existing base research funding, research infrastructure, and scientific expertise, which allows research needs to be met expediently and cost-effectively.

Agricultural Management Alternatives

Soil Erosion

The Riesel Watersheds, originally the Blacklands Experimental Watershed, were established in 1936-1938 along with the North Appalachian Experimental Watershed near Coshocton, OH and another experimental watershed in Hastings, NE. These original USDA-ARS watersheds were established by the research program of the Hydrologic Division of the Soil Conservation Service (USDA-SCS) following severe soil losses from agricultural lands during the Dust Bowl. They were designed to facilitate small watershed-scale research on the impacts of agricultural land management practices on soil erosion and floods (USDA, 1942). Research at these original ARS experimental watersheds quantified soil loss reduction under conservation management systems (Baird, 1948, 1950, 1964; Baird et al., 1970), which was a vital component of the scientific basis of the 20th century conservation farming revolution.

Tillage, Fertilizer, and Chemical Alternatives

Research by TGRP scientists has also established fundamental understanding of the agronomic and environmental effects of various agricultural practices. Improved understanding of tillage impacts on crop production and nutrient loss was developed by Baird and Knisel (1971), Chichester and Richardson (1992), and Richardson and King (1995). The transport of agricultural chemicals was studied by Swoboda et al. (1971), Richardson et al. (1978), and Bovey and Richardson (1991) and used to justify regulatory changes and labeling of these chemicals. Similarly, the offsite transport of inorganic and organic fertilizer nutrients has been studied at the Riesel Watersheds and has contributed to important advancements such as P Index development (e.g., Kissel et al., 1976; Sharpley, 1995; Richardson and King, 1995; Harmel et al., 2005).

Impacts of Land Applying Poultry Litter

One recent research focus of TGRP scientists is economically-wise and environmentally-friendly utilization of poultry litter. This cooperative project between USDA-ARS, Texas A&M AgriLife Research and Extension, and the TSSWCB, which started in 2000, has been crucial in determining sustainable (cost effective and environmentally-friendly) utilization strategies important because the poultry industry has increased dramatically in Central Texas during the last decade. Now the project is recognized as the most comprehensive, long-term study in the U.S. on the effects of land-applying poultry litter as a soil amendment and nutrient source for crop and forage production. To date, this research has addressed soil microbiology, runoff water quality, on-farm economics, nutrient cycling, and natural resource modeling and assessment (e.g., Acosta-Martinez and Harmel, 2006; Green et al., 2007; Vadas et al., 2007; Harmel et al., 2004, 2005, 2008, 2009, 2011). A recently initiated component, which will carry the project into its 13th year, is evaluating the reduction of bacteria runoff and odor emission by in-house windrow composting of litter prior to land application.

Impacts of Enhanced Soil Test Fertilizer Recommendations

Soil test methods recently developed by a TGRP scientist, in partnership with Woods End Laboratory, are rapidly being accepted by commercial laboratories. These enhanced methods provide the foundation of a simple fertilizer recommendation approach that does not rely on the relative yield-crop response curves and "calibration data" that have been used for decades but instead is based on actual, inherent soil fertility (e.g., Haney et al., 2008a, 2008b, 2010; Solvita, 2013). These methods account for all sources of plant available N in the soil, including NO_3-N, available NH_4-N, and mineralizable N, and accurately determine plant available P, thus both inorganic sources (which are typically tested for) and organic sources (which are typically ignored although they do contribute plant available nutrients) are considered in fertilizer recommendations. The agro-economic effects of applying fertilizer at traditional rates versus rates determined with this test are being evaluated along with the water quality impacts.

Cattle Grazing and Soil Health

Several factors, most notable of which are increased input costs and heightened importance of sustainability and soil health, prompted this recently-initiated study comparing typical grazing management to an alternative grazing system designed to improve soil health and increase profitability. Soil quality, water quality, and economic effects are being compared for these two systems implemented on the Riesel Watersheds. Since 2012, the "South Ranch" has been managed with grazing oats on tilled land fertilized with inorganic fertilizer, reliance on hay during winter, separate herds, and best pasture grazing. The "North Ranch" is managed with selected improved pasture over seeded with winter multi-species cover crops, summer multi-species cover crop on cultivated grazed fields instead of inorganic fertilizer application, limited reliance on hay, and planned grazing rotation with one herd. Project partners include the Texas Grazing Lands Conservation Initiative, USDA-ARS, USDA-NRCS, Texas A&M AgriLife Research, Texas A&M Institute of Renewable Natural Resources, Dixon Water Foundation, and the Grazingland Animal Nutrition Laboratory.

Applied Hydrology and Water Quality

The Texas Blackland Prairies ecoregion (Omernik, 1987) is critical in terms of agricultural and urban importance (discussed subsequently in Geographic Coverage at Various Scales section) and is dominated by expansive Vertisol (shrink-swell) clay soils (fig. 1). These ecoregion characteristics require that specific hydrologic relationships be developed to guide design of agricultural conservation practices, urban development, flood control measures, and ecological restoration. TGRP research established these relationships, e.g., land management impacts, temporal trends, and annual peak flow rates and return periods vs. watershed size (Harmel et al., 2003, 2006; Arnold et al., 2005; Allen et al., 2005, 2011). This research minimized safety risks and decreased costs that previously resulted from overly conservative safety factors and uncertainty due to lack of regional relationships. More recently, Vertisol shrink-swell processes (Dinka et al., 2013) and Vertisol-specific model routines are being developed by Texas A&M AgriLife Research, Baylor Univ., and USDA-ARS.

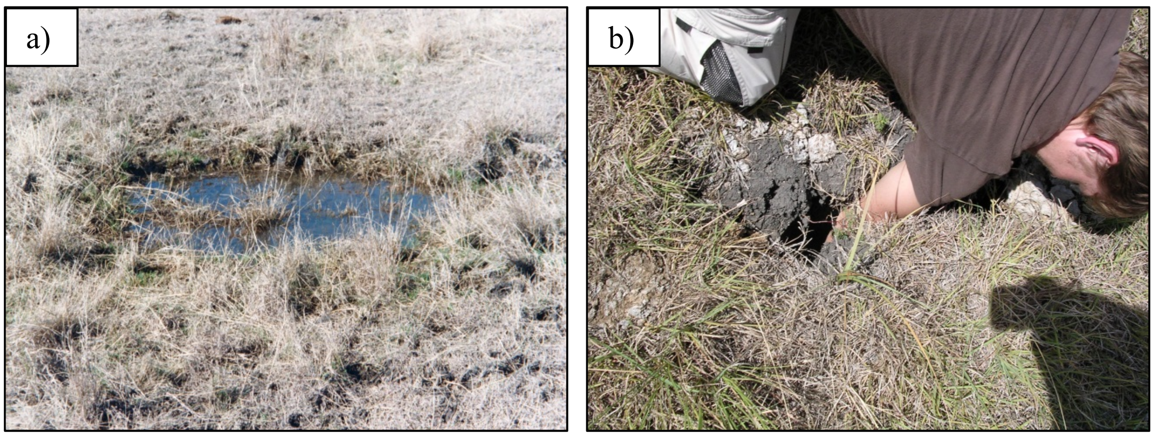


Figure 1. Vertisol features; a) gilgai microtopography, and b) extensive crack formation in extended dry periods.

In additional to process-based understanding of Vertisol hydrology, long-term data records and monitoring infrastructure is continually utilized by SPRS scientists to study topics related to climate change, land use impacts, and water quality sampling instrumentation and methodology (e.g., Arnold et al., 2005; Harmel et al., 2003, 2006; Amidu and Dunbar, 2007; Allen et al., 2005, 2011). Current applied hydrology and water quality research is addressing the effect of agricultural conservation practices on runoff quantity and quality through the Conservation Effects Assessment Project (CEAP) in cooperation with USDA-ARS, USDA-NRCS, and Texas A&M AgriLife Research; holding times and storage conditions on measured *E. coli* concentrations with refrigerated and non-refrigerated automated samplers in partnership with USDA-ARS, EPA, TSSWCB, TWRI, and Texas A&M AgriLife Research; *E. coli* runoff as affected by land use and management in partnership with the TSSWCB, TWRI, and Texas A&M AgriLife Research; and evaluating proximal soil sensing devices and rainfall capture of the gilgai led by Texas A&M AgriLife Research.

Additional research at the Riesel Watersheds, throughout the Texas Gulf Region (HUC2-12), and around the nation by TGRP scientists has developed understanding of the complex interrelationships between lateral flow, shallow subsurface flow, and stream baseflow. Resulting baseflow relationships (Arnold et al., 1995, 1999) have been incorporated into the Soil and Water Assessment Tool (SWAT) to enhance water budget assessment (e.g., Arnold et al., 2000; Santhi et al., 2008). In addition, research on shale weathering and soil erosion has used submerged jet testing (Hanson and Cook, 2004) to assess stream channel erodibility within shale-dominated watersheds (Allen et al., 1997). This process-based understanding has also been incorporated into SWAT (e.g., Allen et al., 1999, 2002, 2008) to assess stream erosion, deposition, and sediment transport and to establish riparian setback ordinances, which are critical issues in this rapidly-urbanizing region.

Watershed/Agro-Ecosystem Modeling

TGRP scientists have developed the world's leading watershed/agro-ecosystem models. These models integrate scientific understanding developed from basic and applied research into simulation models that are relied upon as research and decision support tools by numerous national and international customers. As powerful integrators of TGRP research and because of the scientific basis provided by TGRP research, these models allow understanding to be "scaled up" to the watershed, regional, national, and continental scale where empirical study is impractical. No research network can provide sufficient data and results across the complete spectrum of contemporary or emerging needs related to sustainable agro-ecosystem management; therefore, models such as SWAT (discussed subsequently) are necessary for science-based, large-scale, agro-ecosystem decision making.

TGRP scientists developed the EPIC/APEX (Williams and Sharpley, 1989), GLEAMS (Knisel, 1993), and SWAT (Arnold et al., 1998, 2012) watershed models, which are now applied worldwide to manage field-, farm-, and basin-scale water quality and to support natural resource decision-making and policy. Data from the Riesel Watersheds was used to develop model routines (e.g., Williams et al., 1971) and to calibrate and validate these models (e.g., Arnold and Williams, 1987). In addition, TGRP scientists and data have been used to perform subsequent model development and evaluation (e.g., Richardson and King, 1995; King et al., 1996; Ramanarayanan et al., 1998; Harmel et al., 2000; Green et al., 2007).

The APEX and SWAT models are currently being used around the world for environmental assessment and to determine the impact of land management and climate change on water supply and water quality. Gassman et al. (2007, 2010) provide comprehensive overviews of their worldwide application. For SWAT, these applications include assessments of several of the world's major river basins including the Mekong, Indus, Ganges, Yellow, and Yangtze in China and the Black Sea basin in Europe. In addition, national and continental scale water resource assessments using SWAT have been conducted in North America, Africa, India, and Europe. In the U.S., SWAT and APEX are currently being used by USDA for national conservation policy assessment and development within CEAP (Conservation Effects Assessment Project) and by EPA for assessment of national environmental programs within HAWQS (Hydrologic and Water Quality System). SWAT is the leading model worldwide for watershed scale conservation and environmental assessment with more than 1300 refereed journal articles published on SWAT development, validation, conservation assessment, environmental policy, and climate change analysis (e.g., Jha et al., 2006; Kemanian et al., 2011).

Cooperating scientists at the Texas A&M Spatial Sciences Laboratory, the Texas A&M Blackland Research Center and Extension Center, and Colorado State Univ. are developing improved user interfaces for SWAT and APEX using the latest GIS and web-based technologies. The Texas A&M Spatial Sciences Laboratory leads the training and educational efforts related to the SWAT, APEX, EPIC, and ALMANAC models by conducting user training and introductory workshops around the world. In addition, numerous scientists from around the world are developing new and enhanced process routines for SWAT. Annual international user and developer conferences highlight this commitment to continued model enhancement (**http://swat.tamu.edu**).

TGRP scientists have for decades been world-leaders in crop simulation modeling. TGRP scientists developed ALMANAC (Agricultural Land Management and Numerical Assessment Criteria), which is a process-oriented model designed to simulate the growth and competition of plant communities (Kiniry et al., 1992). It has been extensively used to analyze plant community dynamics, phenology, water use efficiency, and radiation use efficiency and to estimate bioenergy crop yields and bioenergy grasses such as switchgrass (*Panicum virgatum*) (Kiniry et al., 1996, 2005, 2008a, 2008b; McLaughlin et al., 2006; Woli et al., 2012). The model is spatially parameterized and thus capable of realistic predictions over large geographic regions (Behrman et al., 2013). Weather and wind databases are built into the ALMANAC interface, and county soil data from the USDA-NRCS web soil survey are easily imported and utilized by ALMANAC.

The ALMANAC software interface has been extended to predict switchgrass biomass potential across large geographical ranges (Behrman et al., 2013). This implementation of ALMANAC, called GeoALMANAC, is available on the USDA-ARS website. The ALMANAC model was then parameterized across the central and eastern U.S. and used to predict switchgrass productivity for current climate conditions and two climate change scenarios. The relationship between changes in biomass and future temperature and precipitation was analyzed. These predictions were used to locate regions that should be targeted for biomass production to maximize current and future productivity.

Although these TGRP models are applied worldwide, updates and revision are constantly needed to address contemporary and emerging issues, such as emerging contaminant fate and transport, land management alteration, global change, biofuel production, and watershed landscape processes and scaling issues. TGRP scientists are committed to continued development and support of models to ensure they remain state-of-the-art simulation and decision support tools.

Carbon Dynamics and Global Change Impacts

Soil CO_2 respiration and soil biogeochemistry

CO_2 concentrations belowground (in soil pore spaces) are controlled by respiration rates and also by the effective diffusivity of CO_2 through the soil. Cracks act as conduits along which CO_2 respired in the subsurface can escape by diffusion (i.e., high effective diffusivity) and possibly by advection from depth within the soil. A recent study at the Riesel Watersheds investigated the role of soil cracking on soil CO_2. Soil CO_2 concentrations varied seasonally by greater than two orders of magnitude in the Vertisols (Breecker et al., 2013). The lowest CO_2 concentrations at 1 m depth were below 1000 ppmV and occurred during the hottest part of the summer when soil cracks had been open for several months. CO_2 concentrations at 1 m reached 10% during the spring when temperatures increased, the soil was wet, and cracks were closed. Comparison of pore space soil CO_2 concentrations with the magnitude of soil subsidence indicates that the opening and closing of cracks in vertic soils magnifies seasonal variability in soil CO_2 concentrations (Breecker et al., 2013). The large seasonal range of soil CO_2 concentrations probably controls the accumulation of inorganic C ($CaCO_3$) in these soils and recrystallization of $CaCO_3$ in soil parent material (Michel et al., 2013).

Additional research on carbon dynamics at the Riesel Watersheds is investigating carbon cycling mechanisms on native tallgrass prairie, improved pasture, and cultivated land (Univ. of Texas and Duke Univ.) and calcium carbonate formation in Vertisols (NSF grant to Univ. of Texas and Baylor Univ.).

Influence of Rising Atmospheric CO_2 Concentration on Agro-ecosystems

Research by TGRP scientists has established a mechanistic understanding of effects of rising atmospheric CO_2 concentration on grassland production and related ecosystem processes. This USDA-ARS led project, in collaboration with scientists at Brigham Young and Duke, is internationally recognized as among the most impactful CO_2 research programs. Now in its third decade, this project has expanded understanding of plant physiology and water use efficiency, plant-plant interactions, ecosystem-level CO_2 and water exchange, soil C and N cycling, and CO_2 effects on bioenergy plants (e.g., Polley et al., 1993, 2006; Gill et al., 2002, 2006; Fay et al., 2012b). Recent work using unique elongated field chambers (Lysimeter CO_2 Gradient; LYCOG) has demonstrated that the stimulatory effect of higher CO_2 is amplified by shifts in plant species composition that result because CO_2 reduces plant water use, slows soil water depletion, and reduces the frequency with which soil water dips below threshold levels of limitation. The water-saving effect of CO_2 depends, in turn, on soil type (Fay et al., 2009, 2012a; Polley et al., 2012a, 2012b).

Nutrient Network (NutNet)

Previous research on global patterns of nutrient limitation have often relied on meta-analysis techniques, which can be hampered by methodological differences among studies. The Nutrient Network (NutNet), which was initiated to examine global patterns in the effects of nutrient limitation on the structure and function of grassland ecosystems, overcomes this limitation by using standardized experimental and measurement protocols to assess grassland responses to nutrient addition and was recognized as a powerful 'open-source' approach to studying major ecological questions on a global scale (Stokstad, 2011). TGRP scientists have contributed to high-profile NutNet publications, which have called into question long-held views that plant species diversity predicts ecosystem net primary productivity (Adler et al., 2011) and that the abundance of invasive species in their home ranges predicts their abundance where they invade (Firn et al., 2011). This research directly supports TGRP and ARS research on global change effects on the provision of ecosystem goods and services by grasslands.

Air Quality

An air monitoring platform was established by TGRP scientists at the Riesel Watersheds weather station in June 2011. This platform was outfitted with a new electrical board with three circuits which can provide power for multiple instruments. The Air Quality Lab at Baylor Univ. has been operating an atmospheric particulate matter sampler collecting filters and measuring concentrations of PM2.5 (particulate matter < 2.5 µm), particulate organic C, and black C. The particulate organic and black C measurements are the only such measurements in Central Texas, and as such they serve as a regional background for air quality. Carbonaceous particulate matter acts as short lived climate forcers, so background measurements are relevant for considering regional climate forcing. Measurements are taken in alignment with EPA Speciation Trends Network (STN) 1-in-6 day sampling schedule. This air monitoring platform also provides baseline measurements to assess the potential impacts of the new clean coal-fired power plant located in Riesel. Finally, focused studies of air quality impacts of agricultural activities (e.g., poultry litter application) have been initiated by the TGRP and led by Baylor Univ.

Agro-Ecosystem Impacts of Bioenergy Production

Long-Term Biomass Experiment (LTBE)

TGRP scientists and collaborators from Brigham Young Univ., Texas State Univ., USDA-ARS (Lincoln, NE), and the Univ. of Texas recently established the Long-Term Biomass Experiment (LTBE) to evaluate long term biomass/bioenergy potential of monoculture and diverse perennial grass systems in the Southern Great Plains. Native perennial grasslands occupy less than 5% of their original extent in the U.S. Central Plains primarily due to conversion to row-crop agriculture, intensively managed improved perennial pastures, and urbanization. These conversions have meant the loss of high-value ecosystem services that maintain air, soil and water quality, biodiversity, and C sequestration. The return of native perennials should, therefore, restore these high value services. Recent bioenergy initiatives propose returning native grasses such as switchgrass to the landscape as a feedstock for bioenergy production systems; however, little is known about ecosystem service provision from switchgrass monocultures, compared to native multispecies grasslands or existing improved pastures. The LTBE objective is to determine the temporal stability of ecosystem service provision from switchgrass monocultures and low input multispecies grassland. Ecosystem services of primary interest are plant biomass production and soil C storage, and their responses to precipitation variability and invasive plant species (e.g., *Sorghum halapense*, Johnsongrass).

Oilseeds, Grasses, and Crops for Bioenergy Production
In projects with the Office of Naval Research, Hawaiian Commercial and Sugar (HC&S), and the Univ. of Hawaii, the ALMANAC model is being used to simulate novel bioenergy crops such as canola, camelina, napiergrass, energy sorghum, energy cane, and Miscane (Miscanthus-sugar cane cross). Some of these plants have been demonstrated to possess heat-cold and drought tolerance, but crop traits are poorly understood because of their distinct growth habits, which make model parameterization difficult. This research is assessing yield variability, water availability, soil erosion, nutrient losses, salinity, soil organic carbon, and greenhouse gas emissions across the southeastern U.S., in U.S. oilseed production regions, and on the HC&S plantation in Maui.

Ecological Genomics of Switchgrass
In partnership with scientists from the Univ. of Texas at Austin, TGRP scientists are conducting an integrated research program exploring the physiological and genomic responses of the promising biofuel crop switchgrass to altered precipitation scenarios representing the range of environmental conditions predicted by climate prediction models. Results will inform development of improved switchgrass varieties and improve understanding of carbon cycling/sequestration implications.

INFRASTRUCTURE CAPACITY

The TGRP has at its disposal world-class scientific infrastructure highlighted by the:

- USDA-ARS Grassland, Soil and Water Research Laboratory, Temple, TX
  - LYCOG, LTBE, NutNet
- Texas A&M AgriLife Blackland Research and Extension Center, Temple, TX
- Texas A&M Spatial Sciences Laboratory, College Station, TX
- USDA-ARS Riesel Watersheds, Riesel, TX

USDA-ARS Grassland, Soil and Water Research Laboratory
The USDA-ARS Grassland, Soil and Water Research Laboratory is co-located with the Texas A&M AgriLife Blackland Research and Extension Center at the Land and Water Solutions Center in Temple, TX. The USDA-ARS Laboratory contains state-of-the-art computer simulation, laboratory, and greenhouse infrastructure housed in more than 25,000 ft^2 of office and laboratory buildings. Currently, 9 permanent scientists and 2 post docs lead various research projects. In addition, 15 permanent biological, agricultural, hydrologic, and engineering technicians and IT specialists with expertise in water quality, soil science, computer modeling, range science, ecology, and agronomy provide technical expertise and support.

The USDA-ARS Grassland, Soil and Water Research Laboratory is also home to the USDA-NRCS Texas Water Resources Assessment Team and the USDA-NRCS National CEAP Modelling Team. Together with the Texas A&M AgriLife Blackland Research and Extension Center, the combined expertise and technology provide natural resources simulation capabilities that USDA and Congress rely upon to guide U.S. agricultural and conservation policy.

Lysimeter CO_2 Gradient (LYCOG)
The Lysimeter CO_2 Gradient (LYCOG), located at the Grassland, Soil and Water Research Laboratory is a truly unique facility that exposes ecosystems (soils/plants) to a continuous gradient in atmospheric CO_2 spanning pre-Industrial to elevated concentrations. The current iteration of this elongated chamber facility is being used to expose communities of tallgrass prairie plants to CO_2 spanning the pre-Industrial concentration to a level expected by mid-century. The facility consists of two transparent, tunnel-shaped chambers aligned parallel along a north-south axis. Along each chamber are arranged prairie assemblages growing on intact monoliths (1x1x1.5 m deep) of each of three strongly contrasting soil types (silty clay,

sandy loam, clay). The LYCOG experiment, soon entering its 8th year, is providing unprecedented insight into the role of soils in regulating the responses of plant productivity, soil hydrology, and element cycling to the increase in CO_2 experienced to present and anticipated within the century.

Long-Term Biomass Experiment (LTBE)

The LTBE infrastructure consists of 24 replicated 0.63 ha plots planted with switchgrass in monoculture, or with a mixture of 30 native prairie species including common dominant C4 grasses and numerous forbs. In coming years, half of the plots will receive supplemental N, and subplots will be irrigated to minimize water limitation or challenged with introduced Johnsongrass seeds to test invasibility. This experiment provides a core long-term experimental framework within which collaborators can nest more specific experiments. One such experiment will amplify seasonal precipitation variability by deploying rainout shelters and irrigation systems that will intercept, store, and reapply precipitation to impose either drier springs/wetter winters or wetter springs/drier winters to determine effects on above and belowground biomass production, belowground bud bank dynamics, soil respiration, and N cycling.

Nutrient Network (NutNet)

The NutNet site at the Grassland, Soil and Water Research Laboratory follows the standardized experimental design used by all NutNet participants. The experiment uses 24, 5x5 m plots located in a remnant, never-plowed tallgrass prairie. The plots are fertilized each spring with N, P, and K, and are sampled three times each growing season for aboveground net primary productivity, vascular plant species composition, and leaf area index. These data contribute to a database containing comparable data from all 68 NutNet sites. They also provide a unique and critical long-term record of grassland productivity and plant diversity for the Blackland Prairies, a benchmark ecosystem which has been extirpated from essentially all of its former range in the Blackland Prairie of central Texas.

Texas A&M AgriLife Blackland Research and Extension Center, Temple, TX

The Blackland Research and Extension Center employs 13 scientists with expertise in agronomy, range science, hydrology, entomology, agricultural engineering, and economics. These scientists work collaboratively to develop and improve the capabilities of the EPIC, APEX, SWAT, and Phygrow models and develop sound management strategies for agricultural, urban, and military lands.

Texas A&M Spatial Sciences Laboratory, College Station, TX

The Texas A&M Spatial Sciences Laboratory, a state-of-the-art mapping, remote sensing, and GIS laboratory with partnership agreements with Intergraph, Inc. and Trimble Navigation, has been a critical long-term collaborator and contributor to development and training associated with TGRP models including SWAT, APEX, EPIC, and ALMANAC. The Spatial Sciences Laboratory maintains an interdisciplinary team of research scientists, who develop improved user interfaces, web-based technologies, lead training and educational efforts, and provide a seamless integration of TGRP models.

USDA-ARS Riesel Watersheds, Riesel, TX

The Riesel Watersheds is a world-renowned historic research facility. The structures dating from the late 1930's were constructed by the Civilian Conservation Corps (CCC), part of the New Deal of President Franklin D. Roosevelt. The Riesel Watersheds, were established along with the North Appalachian Experimental Watershed, Coshocton, OH (closed 2011) and the Central Great Plains Experimental Watershed, Hastings, NE (closed 1967), resulting from the realization of the importance of hydrologic processes on agricultural fields and watersheds. Their purpose was to determine the impact of agricultural land management on soil erosion, floods, water resources, and the agricultural economy.

The original infrastructure at Riesel included multiple watersheds and rain gauges on property purchased by the USDA and on adjoining private land in the Brushy Creek watershed. Hydrologic, soil erosion, and air temperature data have been collected continuously on selected sites since the late 1930s (data discussed subsequently). Installation of a VHF radiotelemetry network in 2001 improved data quality and collection efficiency (fig. 2a, b). From the onsite base station, equipment maintenance and calibration are performed and realtime conditions are monitored. An automated data collection schedule runs continuously and collects data daily from each field station.

Runoff data collection began in 1938 and continued during various periods from 40 watersheds (0.1 to 2372 ha). Currently, 17 runoff stations are in operation on remnant prairie, improved pasture, and cultivated cropland. Ten runoff stations are located at the outlets of small, single land use watersheds (1.2 to 8.4 ha) to measure "edge of field" processes (fig. 3). Four stations are located at the outlet of 0.1 ha plots. Three stations are located at the outlet of larger downstream watersheds (17.1 to 125.1 ha) with mixed land uses to evaluate integrated processes. Each of these runoff structures is instrumented with a shaft encoder as the primary water level (stage) recording device and with a float gauge chart recorder and a bubbler level recorder as backup devices. Since 2000, shallow groundwater levels in seven wells have been monitored twice weekly with a hand-held "e-line" gauge. Electronic automated samplers were installed in 2001 to collect runoff samples (fig. 2c), which are analyzed for nutrient, sediment, and bacteria concentrations. Currently, 15 rain gauges are in operation within 340 ha, which makes Riesel one of the denser rain gauge networks in the world. Electronic tipping-bucket gauges with dataloggers were installed in the late 1990’s and record rain data on 10 minute intervals (fig. 2b). A standard rain gauge at each site is used as a backup and calibration device. Since 1990, air temperature, solar radiation, wind speed and direction, precipitation, and soil temperature have been measured by an onsite weather station. Prior to 1990, only daily maximum and minimum air temperature, daily pan evaporation, and precipitation were measured continuously.

Figure 2. Selected hydrologic instrumentation at the Riesel Watersheds; a) Campbell Scientific data logger and telemetry radio and modem, b) rain guage station with a tipping bucket and standard gauge and radio telemetry equipment, and c) ISCO autosampler.

In addition to the hydrologic and meteorological infrastructure, the Riesel Watersheds includes 340 ha of USDA-ARS owned and operated land, along with recently renovated laboratory, shop, office, and meeting facilities. Its federally controlled status allows research to be quickly redirected to address emerging issues. As common in the region, present day agricultural land use includes cattle production on pasture and rangeland, and corn, wheat, grain sorghum, and oat production under a wide range of tillage and management operations. ***In addition, 18 ha of remnant (native) prairie are maintained and utilized to provide background information on water quality and plant species diversity and on mechanisms regulating plant productivity and temporal stability of productivity.***

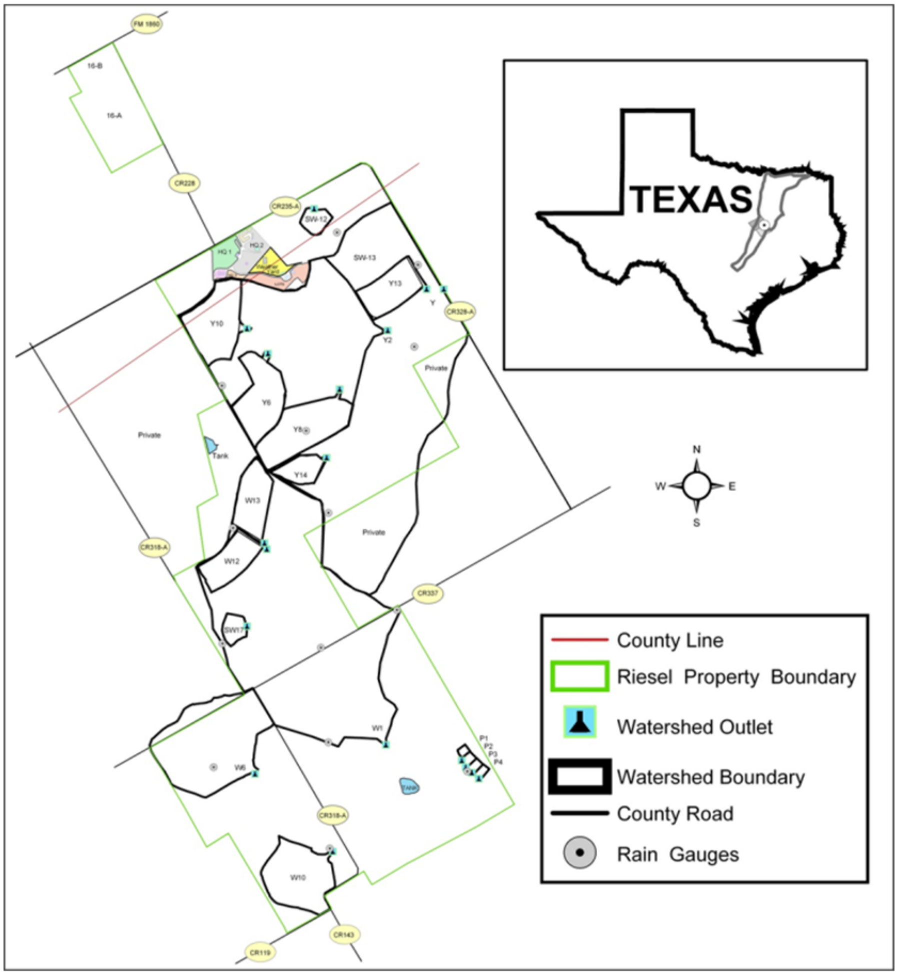


Figure 3. Active experimental watersheds and rain gauges at the USDA-ARS Riesel Watersheds.

DATA RICHNESS

The length, breadth, depth, and quality of the existing data record collected and managed by the TGRP is extraordinary. The Riesel Watersheds have a 75 year legacy data base, highlighted by hydrologic, soil erosion, and land management data (discussed subsequently) that have been subjected to extensive quality assurance/quality control (QA/QC). In addition, the Grassland, Soil and Water Research Laboratory and Blackland Research and Extension Center have a 100 year weather data set. The 7 year LYCOG data set is also available to researchers from other institutions upon request. It includes 30 min avg. ambient light level (and CO_2 concentration, temperature, relatively humidity along the CO_2 gradient), daily soil water loss, biweekly soil water content by depth, monthly leaf area index and soil respiration, and annual plant productivity by species.

Riesel Watersheds

More than 1400 site-years of daily and sub-daily precipitation data and more than 1300 site-years of daily and subdaily flow (baseflow and runoff) have been collected from the Riesel Watersheds and made publically available (Table 1). In addition, more than 600 site-years of soil loss data and other meteorological data have been collected and made available on the internet. More recently, a great deal of storm runoff and baseflow water quality data have collected. For thirteen watersheds, nutrient concentrations (NO_3-N, NH_4-N, and PO_4-P) have been measured in every runoff event since 2000 and in baseflow since 2004. Similarly, bacteria (*E. coli*) concentrations have been determined for every runoff event since 2008. These data are being added to our website (**www.ars.usda.gov/spa/hydro-data)** and to the STEWARDS database (**http://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html**).

Table 1: Summary of publically available legacy data for USDA-ARS Riesel Watersheds, and USDA-ARS Grassland, Soil and Water Research Laboratory and Texas A&M AgriLife Blackland Research and Extension Center (**www.ars.usda.gov/spa/hydro-data**).

Data Type (Riesel, TX)	Record	Record Length (yr)	# Sites	Site-years Subdaily Data	Site-years Daily Data	# Sites (≥ 50 yr)
Flow	1938-2012	75	40	1384	1392	10
Sediment loss	1939-2012	74	22	479	658	3
Lateral subsurface flow	2001-2012	12	1	-	12	0
Land management	1944-2012	69	126	-	-	10
Precipitation	1938-2012	75	57	1470	1474	13
Air temperature	1940-2012	73	1	9	73	1
Soil temperature	1997-2012	16	1	9	16	0
Relative humidity	1998-2012	15	1	9	15	0
Evaporation	1944-2012	69	1	-	69	1
Radiation	1990-2012	23	1	9	23	0
Data Type (Temple, TX)						
Precipitation, air temperature	1914-2012	99	1	-	-	1
Soil temperature, radiation, relative humidity, wind speed	1996-2012	17	1	-	-	-

In addition to hydrologic and water quality data, the Riesel Watersheds have produced an extensive land use/land management data record dating to 1938 that provides an historical record of evolving management practices, such as tillage, planting, harvest, cropping systems. This data record including native tallgrass prairie, pasture, hay, and cultivated land has proven extremely valuable for quantifying impacts of changing land use/ land management related to floods (Baird, 1948), droughts (Allen et al., 2011), soil C (Potter et al., 1999; Potter, 2006), water quality (Harmel et al., 2009), and global change (Harmel et al., 2003, 2006), and will remain so in the future. In fact, the only known historic account of the 1950's drought history including sediment data was produced from Riesel data (Allen et al., 2011).

DATA AVAILABILITY (ACCESSIBILITY)

Riesel Watersheds

It is critical that data from the Riesel Watersheds be publically available. That fundamental belief of Grassland, Soil and Water Research Laboratory scientists launched a monumental effort in the 1990's to quality check and place the entire Riesel data record on the web in 2002 (www.ars.usda.gov/spa/hydro-data). In addition to our locally operated, publically-available internet database, many of the data from Riesel have also been included to the STEWARDS database (http://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html).

Our locally-led effort was the first, or one of the first, of such efforts following those of Jane Thurman to compile ARS watershed data in a single repository. Runoff, precipitation, sediment, and land management data were formatted consistently, quality-checked, placed on the web, and published (Harmel et al., 2003, 2006). Then each year since 2002, the previous year's data have been quality-checked, incorporated into the data record, and placed on the web within 3 months of the year end. The resulting, massive 75 year legacy database has been used by scientists worldwide to develop and evaluate natural resource models, to evaluate long-term ecological trends and climate change, and to better understand Vertisol hydrology.

Additional Data

In addition to the Riesel data, 100 years of weather data from the USDA-ARS Grassland, Soil and Water Research Laboratory and Texas A&M AgriLife Blackland Research and Extension Center are also available **(www.ars.usda.gov/spa/hydro-data)**. Although, not available on the internet, the 7 year LYCOG data set is available to researchers from other institutions upon request.

GEOGRAPHIC COVERAGE AT VARIOUS SCALES

The TGRP provides critical coverage of the Texas-Gulf HUC2-12 basin (see cover page map), which is characterized by socio-economic dependence on agriculture, by rapid population and commercial growth, and by extensive on-going land use change. The Texas Gulf has 3 of the 10 largest cities in the U.S. (Dallas, Houston, San Antonio) and 4 of the top 10 fastest growing cities (Austin, Dallas, Houston, San Antonio) according to Forbes (2012).

The Riesel Watersheds and most of the TGRP infrastructure lie within the 4.45 million ha Texas Blackland Prairies ecoregion (Omernik, 1987). Thus, the TGRP also provides coverage of this critical agricultural and urban ecoregion. Present day agricultural land use in Texas Blackland Prairies consists of cattle production on pasture and rangeland, and corn, wheat, grain sorghum, and oat production under a wide range of tillage and management operations. The ecoregion also contains major metropolitan areas, including Dallas and San Antonio, which are in the top 10 U.S. cities in population and growth, and Austin, which is the fastest growing city in the U.S. (Forbes, 2012). Houston Black clay soils (fine, smectitic, thermic, udic Haplustert), recognized throughout the world as the classic Vertisol, dominate the ecoregion. These highly expansive clays, which have a typical particle size distribution of 17% sand, 28% silt, and 55% clay, shrink and swell considerably with changes in moisture content. These soils are very slowly permeable when wet (approximate saturated hydraulic conductivity of 1.5 mm/h); however, preferential flow associated with soil cracks contributes to high infiltration rates when the soil is dry (Allen et al., 2005).

While the TGRP does provide critical geographic coverage for Texas Blackland Prairies ecoregion and the Texas-Gulf HUC2-12 basin, no research network can provide sufficient data and results across the entirety of spatial scales and address the complete spectrum of contemporary or emerging needs. Therefore, models such as SWAT are critical to “scale up” scientific understanding to application and evaluation at local, watershed, regional, national, and continental scales, which is critical to sustainable agro-ecosystem management. As such, models developed by TGRP scientists have frequently been relied upon for multi-scale analyses. One recent example, involved using data from the Riesel Watersheds and the Leon River collected in the CEAP Watershed Assessment Study to improve Vertisol shrinking and swelling, animal waste management, C dynamics, ground water recharge, and erosion processes in the SWAT and APEX models. The enhancements and validation of these models provided increased confidence in the CEAP National Cropland Assessment, which will ultimately lead to scientifically-sound USDA conservation policy.

PARTNERSHIPS

It is clear that the longstanding partnerships within the TGRP are a key component in its long-term productivity and success. A comprehensive discussion of past and current partnerships would be excessive in this proposal but should be readily apparent in the previous discussion. The research conducted by TGRP scientists and the technology transferred from that research clearly exemplifies the depth and strength of the partnerships between USDA-ARS, USDA-NRCS, Texas A&M AgriLife Extension and Research, TSSWCB (and Texas Soil and Water Conservation Districts), EPA, Texas A&M Univ., Univ. of Texas, and Baylor Univ., as well as numerous local agricultural producers, state and federal agencies, and universities. This partnership is not duplicative but allows each agency and institution to apply their specialized expertise and experience. Specifically, technologies are developed by USDA-ARS and university researchers, transferred to producers by USDA-NRCS, Texas A&M AgriLife Extension, and Soil and Water Conservation Districts, and put on the ground by producers with the technical and sometimes financial support of USDA-NRCS, EPA, TCEQ, and TSSWCB.

In addition to these core partnerships, many researchers from universities, and other research organizations and ARS laboratories, have and continue to utilize TGRP infrastructure. For example, recent research led by non-TGRP researchers at the Riesel Watersheds has been conducted on land use effects on C and nutrient cycling (Jackson et al., 2002; McCulley and Jackson, 2012); climate change impacts on rangeland vegetation (Derner et al., 2011); and soil, vegetation, and climate influences on groundwater recharge (Kim and Jackson, 2012).

In addition to research, education and outreach activities are critical to and enthusiastically conducted by TGRP scientists. Such activities are far too numerous to describe in the current proposal, but two examples are provided. Baylor Univ. and Texas A&M Univ. use the Riesel Watersheds to teach undergraduate and graduate students about hydrology, land use impacts, and hydrologic and meteorologic instrumentation. The TGRP is partnering with New Mexico State Univ. and the Univ. of Texas at El Paso in the BGREEN (Building Regional Energy and Educational Alliances) program to create a network of sustainable energy researchers, educators, USDA agencies, and non-profits to coordinate efforts and increase educational and post-graduation opportunities for Hispanic students pursuing careers in sustainable energy and agricultural research. Three interns concentrated on field research related to bioenergy production in 2012 and four more are scheduled for the summer of 2013.

INSTITUTIONAL COMMITMENT

USDA-ARS and our University partners are committed to continue our longstanding partnership and participate in LTAR for decades to come. The Grassland, Soil and Water Research Laboratory has been a leading advocate for experimental watersheds, the USDA-ARS watershed network, and a national network of watershed and agro-ecosystem research sites. The commitment is exemplified in Harmel et al. (2007) citing Slaughter (2000), who stated that the current and unforeseen future value of experimental watersheds should not be disregarded in budget decisions for long-term research and monitoring. Harmel et al. (2007) stated that "Despite budgetary and political pressures, the demonstrated accomplishments and certain future value cannot be overlooked in decisions related to established, long-term experimental watersheds. The USDA-ARS watersheds are uniquely positioned with legacy data, established monitoring infrastructure, watershed land control, and scientific expertise. As such, the USDA-ARS watershed network can be relied upon to provide science, technology, and data to satisfy competing water resource demands necessary for economic and environmental sustainability. Committed support of the USDA-ARS and other federal experimental watersheds has yielded critical understanding and technology related to water resources. Such commitment must remain a national priority."

In addition, USDA-ARS Southern Plains Area leadership is committed to the long-term operation of the Grassland, Soil and Water Research Laboratory and its scientific infrastructure including the Riesel Watersheds, LTBE, and LYCOG. This commitment is detailed in the letter of support (attached). Considerable funding has been invested in recent years to renovate facilities and research infrastructure and purchase state-of-the-art instrumentation to improve appearance, functionality, and energy efficiency.

ADDITIONAL FACTORS
The TGRP has existing water/energy balance and carbon flux/sequestration research and has a proven capacity to integrate across soil, water, and air processes (discussed throughout) and has formal associations with other long-term research networks as described subsequently.

***GRACEnet* -** Research at the USDA-ARS Grassland, Soil and Water Research Laboratory contributes to the ARS GRACEnet project and follows applicable GRACEnet protocols and technical guidelines (**www.ars.usda.gov/research/programs/programs.htm?np_code=212&docid=21223**)

***USDA-ARS CEAP Benchmark Watershed* -** The Riesel Watersheds are USDA-ARS Conservation Effects Assessment Project (CEAP) Benchmark Watersheds. CEAP, which is an Office of Management and Budget (OMB) and congressionally-mandated program, has and will continue to support USDA efforts to improve the cost-effectiveness of its conservation programs.

***ASABE Historical Landmark Designation* -** In 2012, the American Society of Agricultural and Biological Engineers (ASABE) designated the original USDA-ARS Experimental Watersheds (Riesel, TX; Hastings, NE; Coshocton, OH) as a National Historic Landmark of Agricultural and Biological Engineering. These watersheds were the foundation for the vibrant, national USDA-ARS experimental watershed network that continues to produce sound science and engineering related to soil and water.

***National Science Foundation Critical Zone Observatory (CZO)* -** The Riesel Watersheds are one of two primary Critical Zone Observatory sites in a 2013 National Science Foundation proposal by TGRP cooperators at Baylor, Rice, Texas, and Texas A&M universities. This request for inclusion illustrates the potential for increased leveraging of the TGRP by other networks and collaborators.

***Nutrient Network (NutNet)* -** The USDA-ARS Grassland, Soil and Water Research Laboratory is one of 68 Nutrient Network (NutNet) sites in 12 countries. This global research network was initiated in 2007 and is producing major findings on global patterns of grassland ecosystem structure and function.

USDA-ARS Southern Regional Biofuel Center
The Grassland, Soil and Water Research Laboratory is home to one of five USDA-ARS Regional Biofuel Centers, which assist in development of dependable biofuel feedstock supplies for production of advanced biofuels to meet legislated goals and market demand and to enable rural areas to benefit economically.

***EPA Speciation Trends Network (STN)* -** The air monitoring platform, established by TGRP scientists at the Riesel Watersheds weather station in 2011, provides air quality data to the EPA Speciation Trends Network (STN).

***EcoTrends Project* -** Although not formally within the LTER Network, the Riesel Watersheds were included with other ARS and Forest Service sites and the 26 LTER sites in the EcoTrends project.

RESPONSIBILITIES OF LTAR NETWORK MEMBERS
The TGRP is willing and committed to meet data quality-control procedures, collection, and presentation requirements; to participate in annual LTAR Network meetings/workshops; to undergo a formal review process every 5 years; and to encourage and welcome research partners from other ARS locations and from outside ARS, including other governmental agencies, universities, and the private sector. The balance between consistent and appropriate methods across sites and the practical limitations of such is of particular interest to the Grassland, Soil and Water Research Laboratory. In fact, one of our scientists (Harmel) provides a leading voice on this issue representing USDA-ARS on the Methods and Data Comparability Board of the National Water Monitoring Council.

REFERENCES – Selected publications produced from TGRP watershed/agro-ecosystem modeling (only selected publication from TGRP modeling research are presented because SWAT alone has produced more than 1300 publications)

Arnold, J. G., D. N. Moriasi, P. W. Gassman, K. C. Abbaspour, M. J. White, R. Srinivasan, C. Santhi, R. D. Harmel, A. van Griensven, M. W. Van Liew, N. Kannan, and M. K. Jha. 2012. SWAT: Model use, calibration, and validation. Trans. ASABE 55(4):1491-1508.

Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. 1998. Large-area hydrologic modeling and assessment: Part I. Model development. J. American Water Resources Assoc. 34(1): 73-89.

Arnold, J. G., and J. R. Williams. 1987. Validation of SWRRB - Simulation for Water Resources in Rural Basins. J. Water Resources Planning Mgmt. 113(2): 243-256.

Behrman, K.D., J.R. Kiniry, M. Winchell, T.E. Juenger, and T.H. Keitt. 2013. Spatial forecasting of switchgrass productivity under current and future climate change scenarios. Ecol. Applications 23(1): 73-85.

Gassman, P. W., J. R. Williams, X. Wang, A. Saleh, E. Osei, L. M. Hauck, R. C. Izaurralde, J. D. Flowers. 2010. The Agricultural Policy Environmental Extender (APEX) model: An emerging tool for landscape and watershed environmental analysis. Trans. ASABE 53(3): 711-740.

Gassman, P. W., M. Reyes, C. H. Green, and J. G. Arnold. 2007. The Soil and Water Assessment Tool: Historical development, applications, and future research directions. Trans. ASABE 50(4):1211-1250.

Green, C. H., J. G. Arnold, J. R. Williams, R. Haney, and R. D. Harmel. 2007. Soil and Water Assessment Tool hydrologic and water quality evaluation of poultry litter application to small-scale subwatersheds in Texas. Trans. ASABE 50(4): 1199-1209.

Jha, M., J.G. Arnold, P. W. Gassman., and R. Gu. 2006. Climate change sensitivity of water yield in the upper Mississippi river basin. J. American Water Resources Assoc. 42(4): 997-1016.

Kemanian, A. R., S. Julich, V. S. Manoranjan, and J. G. Arnold. 2011. Integrating soil carbon cycling with that of nitrogen and phosphorus in the watershed model SWAT: Theory and model testing. Ecol. Modelling 222(12): 1913-1921.

Kiniry, J. R., L. Lynd, N. Greene, M. V. Johnson, M. Casler, and M. S. Laser. 2008a. Biofuels and water use: Comparison of maize and switchgrass and general perspectives. Pages 17-30 in J. H. Wright and D. A. Evans, editors. New Research on Biofuels. Nova Science, New York, New York, USA.

Kiniry, J. R., M. R. Schmer, K. P. Vogel, and R. B. Mitchell. 2008b. Switchgrass biomass simulation at diverse sites in the northern Great Plains of the US. BioEnergy Res. 1: 259-264.

Kiniry, J. R., K. A. Cassida, M. A. Hussey, J. P. Muir, W. R. Ocumpaugh, J. C. Read, R. L. Reed, M. A. Sanderson, B. C. Venuto, and J. R. Williams. 2005. Switchgrass simulation by the ALMANAC model at diverse sites in the southern US. Biomass Bioenergy 29: 419-425.

Kiniry, J. R., M. A. Sanderson, J. R. Williams, C. R. Tischler, M. A. Hussey, W. R. Ocumpaugh, J. C. Read, G. Van Esbroeck, and R. L. Reed. 1996. Simulating Alamo switchgrass with the ALMANAC model. Agronomy J. 88: 602-606.

Kiniry, J. R., J. R. Williams, P. W. Gassman, and P. Debaeke. 1992. General, process-oriented model for two competing plant species. Trans. ASAE 35: 801-810.

McLaughlin, S. B., J. R. Kiniry, C. M. Taliaferro, D. De La, Torre Ugarte, and D. L. Sparks. 2006. Projecting yield and utilization potential of switchgrass as an energy crop. Adv. Agronomy 90: 267-297.

Williams, J. R., and A. N. Sharpley. 1989. EPIC - Erosion/productivity impact calculator: 1. Model documentation. Tech. Bulletin No. 1768. Washington, D.C.: USDA-ARS.

Woli, P., J. Paz, D. Lang, B. Baldwin, and J. Kiniry. 2012. Soil and variety effects on the energy and carbon balances of switchgrass-derived ethanol. J. Sustainable Bioenergy Systems 2(4): 65-74.

REFERENCES – Publications produced from research at the LYCOG and its predecessors

Fay, P. A., V. L. Jin, D. A. Way, K. N. Potter, R. A. Gill, R. B. Jackson and H. W. Polley. 2012a. Soil-mediated effects of subambient to increased carbon dioxide on grassland productivity. Nature Climate Change 2:742-746.

Fay, P. A., H. W. Polley, V. L. Jin, and M. J. Aspinwall. 2012b. Productivity of well-watered Panicum virgatum does not increase with CO_2 enrichment. J. Plant Ecol. doi:10.1093/jpe/rts007.

Gill, R. A., L. J. Anderson, H. W. Polley, H. B. Johnson, and R. B. Jackson. 2006. Potential nitrogen constraints on soil carbon sequestration under low and elevated atmospheric CO2. Ecol.87: 41-52.

Gill, R. A., H. W. Polley, H. B. Johnson, L. J. Anderson, H. Maherali, and R. B. Jackson. 2002. Nonlinear grassland responses to past and future atmospheric CO_2. Nature 417:279-282.

Polley, H. W., V. L. Jin, and P. A. Fay. 2012a. CO_2-caused change in plant species composition rivals the shift in vegetation between mid-grass and tallgrass prairies. Global Change Biol. 18:700-710.

Polley, H. W., V. L. Jin, and P. A. Fay. 2012b. Feedback from plant species change amplifies CO_2 enhancement of grassland productivity. Global Change Biol. 18:2813-2823.

Polley, H. W., P. C. Mielnick, W. A. Dugas, H. B. Johnson, and J. Sanabria. 2006. Increasing CO2 from subambient to elevated concentrations increases grassland respiration per unit of net carbon fixation. Global Change Biol. 12: 1390-1399.

Polley, H. W., H. B. Johnson, B. D. Marino, and H. S. Mayeux. 1993. Increase in plant water-use efficiency and biomass from glacial to present CO_2 concentrations. Nature 361: 61-64.

REFERENCES – Publications produced from research at the Riesel Watersheds (since 2000)

Acosta-Martínez, V., and R. D. Harmel. 2006. Soil microbial communities and enzyme activities under various poultry litter application rates. J. Environ. Qual. 35:1309-1318.

Allen, P. M., R. D. Harmel, J. A. Dunbar, and J. G. Arnold. 2011. Upland contribution of sediment and runoff during extreme drought: A study of the 1947-1956 drought in the Blackland Prairie, Texas. J. Hydrol. 407:1-11.

Allen, P. M., R. D. Harmel, J. G. Arnold, B. Plant, J. Yeldermann, and K. W. King. 2005. Field data and flow system response in clay (vertisol) shale terrain, north central Texas, USA. Hydrol. Processes 19(14): 2719-2736.

Amidu, S. A., and J. A. Dunbar. 2007. Geoelectric studies of seasonal wetting and drying of a Texas Vertisol. Vadose Zone J. 6:511-523.

Arnold, J. G., K. N. Potter, K. W. King, and P. M. Allen. 2005. Estimation of soil cracking and the effect on surface runoff in a Texas Blackland Prairie watershed. Hydrol. Processes 19(3): 589-603.

Breecker, D. O., J. Yoon, L. A. Michel, T. M. Dinka, S. G. Driese, J. S. Mintz, L. C. Nordt, K. D. Romanak, and C. L. S. Morgan. 2013. CO2 concentrations in Vertisols: seasonal variability and shrink-swell. In New Frontiers in Paleopedology and Terrestrial Paleoclimatology. S. G. Driese and L. C. Nordt, eds. SEPM (Society for Sedimentary Geology) Special Publication Volume (In Press).

Derner, J. D., K. R. Hickman, and H. W. Polley. 2011. Decreasing precipitation variability does not elicit major aboveground biomass or plant diversity responses in a mesic rangeland. Rangeland Ecol. Manage. 64:362-367.

Dinka, T. M., C. L. S. Morgan, K. J. McInnes, A. S. Kishné, and R. D. Harmel. 2013. Shrink-swell behavior of soil across a Vertisol catena. J. Hydrol. 476:352-359.

Driese, S. G., J. R. Jacobs, and L. C. Nordt. 2003. Comparison of modern and ancient Vertisols developed on limestone in terms of their geochemistry and parent material. Sedimentary Geol. 157: 49-69.

Harmel, R. D., R. L. Haney, and D. R. Smith. 2011. Effects of annual Turkey litter application on surface soil quality of a Texas Blackland Vertisol. Soil Sci. 176(5):227-236.

Harmel, R. D., and J. G. Arnold. 2010. The Riesel Watershed: A star attraction on the experimental watershed network map. ASABE Resource July/August 2010: 16-18.

Harmel, R. D., D. R. Smith, R. L. Haney, and M. Dozier. 2009. Nitrogen and phosphorus runoff from cropland and pasture fields fertilized with poultry litter. J. Soil Water Conserv. 64(6): 400-412.

Harmel, R. D., C. G. Rossi, T. Dybala, J. Arnold, K. Potter, J. Wolfe, and D. Hoffman. 2008. Conservation Effects Assessment Project research in the Leon River and Riesel watersheds. J. Soil Water Conserv. 63(6):453-460.

Harmel, R. D., J. V. Bonta, and C. W. Richardson. 2007. The original USDA-ARS experimental watersheds in Texas and Ohio: Contributions from the past and visions for the future. Trans. ASABE 50(5):1669-1675.

Harmel, R. D., C. W. Richardson, K. W. King, and P. M. Allen. 2006. Runoff and soil loss relationships for the Texas Blackland Prairies ecoregion. J. Hydrol. 331(3-4): 471-483.

Harmel, R. D., H. A. Torbert, P. B. DeLaune, B. E. Haggard, and R. L. Haney. 2005. Field evaluation of three phosphorus indices on new application sites in Texas. J. Soil Water Conserv. 60(1): 29-42.

Harmel, R. D., H. A. Torbert, B. E. Haggard, R. Haney, and M. Dozier. 2004. Water quality impacts of converting to a poultry litter fertilization strategy. J. Environ. Qual. 33(6): 2229-2242.

Harmel, R. D., K. W. King, C. W. Richardson, and J. R. Williams. 2003. Long-term precipitation analyses for the central Texas Blackland prairie. Trans. ASAE 46(5): 1381-1388.

Harmel, R. D., C. W. Richardson, and K. W. King. 2000. Hydrologic response of a small watershed model to generated precipitation. Trans. ASAE 43(6): 1483-1488.

Jackson, R. B., J. L. Banner, E. G. Jobbagy, W. T. Pockman, and D. H. Wall. 2002. Ecosystem carbon loss with woody plant invasion of grasslands. Nature 418:623-626.

Kim, J. H., and R. B. Jackson. 2012. A global analysis of groundwater recharge for vegetation, climate, and soils. Vadose Zone J. doi:10.2136/vzj2011.0021RA.

Michel, L. A., S. G. Driese, L. C. Nordt, D. O. Breecker, and D. M. Labotka. 2013. Stable carbon isotope geochemistry of Vertisols formed on marine carbonates and implications for deep-time paleoenvironmental reconstructions. J. Sediment. Res. (In Press).

McCulley, R. L., and R. B. Jackson. 2012. Conversion of tallgrass prairie to Woodland: Consequence for carbon and nitrogen cycling. Am. Midl. Nat. 167:307-321.

Nordt, L., M. Orosz, S. Driese, and J. Tubbs. 2006. Vertisol carbonate properties in relation to mean annual precipitation: Implications for paleoprecipitation estimates. J. Geol. 114: 501-510.

Potter, K.N. 2006. Soil carbon content after 55 years of management of a Vertisol in central Texas J. Soil Water Conserv. 61(6): 338-343

Vadas, P. A., R. D. Harmel, and P. J. A. Kleinman. 2007. Transformations of soil and manure phosphorus after surface application of manure to field plots. Nutr. Cycl. Agroecosyst. 77:83-99

REFERENCES – Publications produced from research at the Riesel Watersheds (prior to 2000)

Baird, R. W. 1964. Sediment yields from Blackland watersheds. Trans. ASAE 7(4): 454-465.

Baird, R. W. 1950. Rates and amounts of runoff for the Blacklands of Texas. Tech. Bulletin No. 1022. Washington, D.C.: USDA.

Baird, R. W. 1948. Runoff and soil conservation practices. Agric. Eng. 29(5): 216-217.

Baird, R. W., and W. G. Knisel. 1971. Soil conservation practices and crop production in the Blacklands of Texas. Conservation Research Report No. 15. Washington, D.C.: USDA.

Baird, R. W., C. W. Richardson, and W. G. Knisel. 1970. Effects of conservation practices on storm runoff in the Texas Blackland Prairie. Tech. Bulletin No. 1406. Washington, D.C.: USDA.

Bovey, R. W., and C. W. Richardson. 1991. Dissipation of clopyralid and picloram in soil and seep flow in the Blacklands of Texas. J. Environ. Qual. 20(3): 528-531.

Chichester, F. W., and C. W. Richardson. 1992. Sediment and nutrient loss from clay soils as affected by tillage. J. Environ. Qual. 21(4): 587-590.

King, K. W., C. W. Richardson, and J. R. Williams. 1996. Simulation of sediment and nitrate loss on a vertisol with conservation tillage practices. Trans. ASAE 39(6): 2139-2145.

Kissel, D. W., C. W. Richardson, and E. Burnett. 1976. Losses of nitrogen in surface runoff on the Blackland Prairie of Texas. J. Environ. Qual. 5(3): 288-293.
Knisel, W. G. 1993. GLEAMS - Groundwater Loading Effects of Agricultural Management Systems, v. 2.10. UGA-CPES-BAED Pub. No. 5. Tifton, Ga.: University of Georgia, Coastal Plain Experimental Station.
Potter, K. N., H. A. Torbert, H. B. Johnson, and C. R. Tischler. 1999. Carbon storage after long-term grass establishment on degraded soils. Soil Sci. 164(10): 718-725.
Ramanarayanan, T. S., M. V. Padmanabhan, G. H. Gajanan, and J. R. Williams. 1998. Comparison of simulated and observed runoff and soil loss on three small United States watersheds. In Modelling Soil Erosion by Water, 75-88. J. Boardman and D. Favis-Mortlock, eds. NATO ASI Series. Series 1: Global Environment Change, vol. 55. Berlin, Germany: Springer-Verlag.
Richardson, C. W., and K. W. King. 1995. Erosion and nutrient losses from zero tillage on a clay soil. J. Agric. Eng. Res. 61(2): 81-86.
Richardson, C. W., J. D. Price, and E. Burnett. 1978. Arsenic concentrations in surface runoff from small watersheds in Texas. J. Environ. Qual. 7(2): 189-192.
Sharpley, A. N. 1995. Identifying sites vulnerable to phosphorus loss in agricultural runoff. J. Environ. Qual. 24(5): 947-951.
Swoboda, A. R., G. W. Thomas, F. B. Cady, and R. W. Baird. 1971. Distribution of DDT and toxaphene in Houston Black clay on three watersheds. Environ. Sci. Tech. 5(2): 141-145.
Williams, J. R., E. A. Hiler, and R. W. Baird. 1971. Prediction of sediment yields from small watersheds. Trans. ASAE 14(6): 1157-1162.

OTHER REFERENCES

Allen, P. M., J. G. Arnold, and W. Skipworth. 2008. Prediction of channel degradation rates in urbanizing watersheds. Hydrol. Sci. 53(5): 1013-1029.
Allen, P. M., J. G. Arnold, and W. Skipworth. 2002. Assessment of bedrock channel erosion in urban watersheds. J. American Water Resources Assoc. 38(5): 1477-1492.
Allen, P. M., J. G. Arnold, and E. Jakubowski. 1999. Prediction of stream channel erosion potential. Environ. Eng. Geoscience 5: 339-351.
Allen, P. M., J. G. Arnold, and E. Jakubowski. 1997. Design and testing of a simple submerged jet device for field determination of soil erodibility. Environ. Eng. Geoscience 3: 579-584.
Arnold, J. G., R. S. Muttiah, R. Srinivasan, and P. M. Allen. 2000. Regional estimation of base flow and groundwater recharge in the Upper Mississippi river basin. J. Hydrol. 227: 21-40.
Arnold, J. G., and P. M. Allen. 1999. Automated methods for estimating baseflow and ground water recharge from streamflow records. J. American Water Resources Assoc. 35(2): 411-424.
Arnold, J. G., P. M. Allen, R.S . Muttiah, and G. Bernhardt. 1995. Automated base flow separation and recession analysis techniques. Ground Water 33(6):1010-1018.
Adler, P. B., E. W. Seabloom, E. T. Borer, et al. 2011. Productivity is a poor predictor of plant species richness. Science 333: 1750-1753.
Firn J., J. L. Moore, A. S. MacDougall, et al. 2011. Abundance of introduced species at home predicts abundance away in herbaceous communities. Ecol. Letters. 14: 274-281.
Forbes. 2012. www.forbes.com/pictures/mlj45hfdf/americas-fastest-growing-cities.
Haney, R. L., E. B. Haney, L. R. Hossner, and J. G. Arnold. 2010. Modifications to the new soil extractant H3A-2-1: A multinutrient extractant. Commun. Soil Sci. Plant Analysis 41(12): 1513-1523.
Haney, R. L., W. F. Brinton, and E. Evans. 2008a. Soil CO_2 respiration: Comparison of chemical titration, CO_2 IRGA analysis and the Solvita gel system. Renewable Agric. Food Sys. 23(2): 171-176.
Haney, R. L., W. H. Brinton, and E. Evans. 2008b. Estimating soil carbon, nitrogen, and phosphorus mineralization from short-term carbon dioxide respiration. Commun. Soil Sci. Plant Analysis 39:2706-2720.

Hanson, G. J., and K. R. Cook. 2004. Apparatus, test procedures, and analytical methods to measure soil erodibility in situ. Applied Eng. Agric. 20(4): 455-462.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals Assoc. American Geographers 77: 118-125.

Santhi, C., P. M. Allen, R. S. Muttiah, J. G. Arnold, and P. Tuppad. 2008. Regional estimation of base flow for the conterminous United States by hydrologic landscape regions. J. Hydrol. 351(1-2): 139-153.

Slaughter, C. W. 2000. Long-term water data ... wanted? needed? available? Water Resources IMPACT 2(4): 2-5.

Solvita. 2013. Haney-Brinton Test for Active Carbon, Biomass and N + P Mineralization Potential. http://woodsend.org/consulting/soil-quality. Accessed January 11, 2013.

Stokstad, E. 2011. Open-source ecology takes root across the world. Science 334: 308-309.

USDA. 1942. The agriculture, soils, geology, and topography of the Blacklands experimental watershed, Waco, Texas. Hydrologic Bulletin No. 5. Washington, D.C.: USDA-SCS.

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