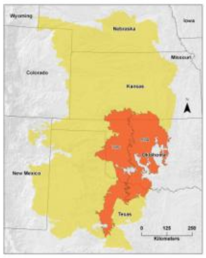
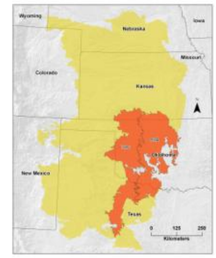
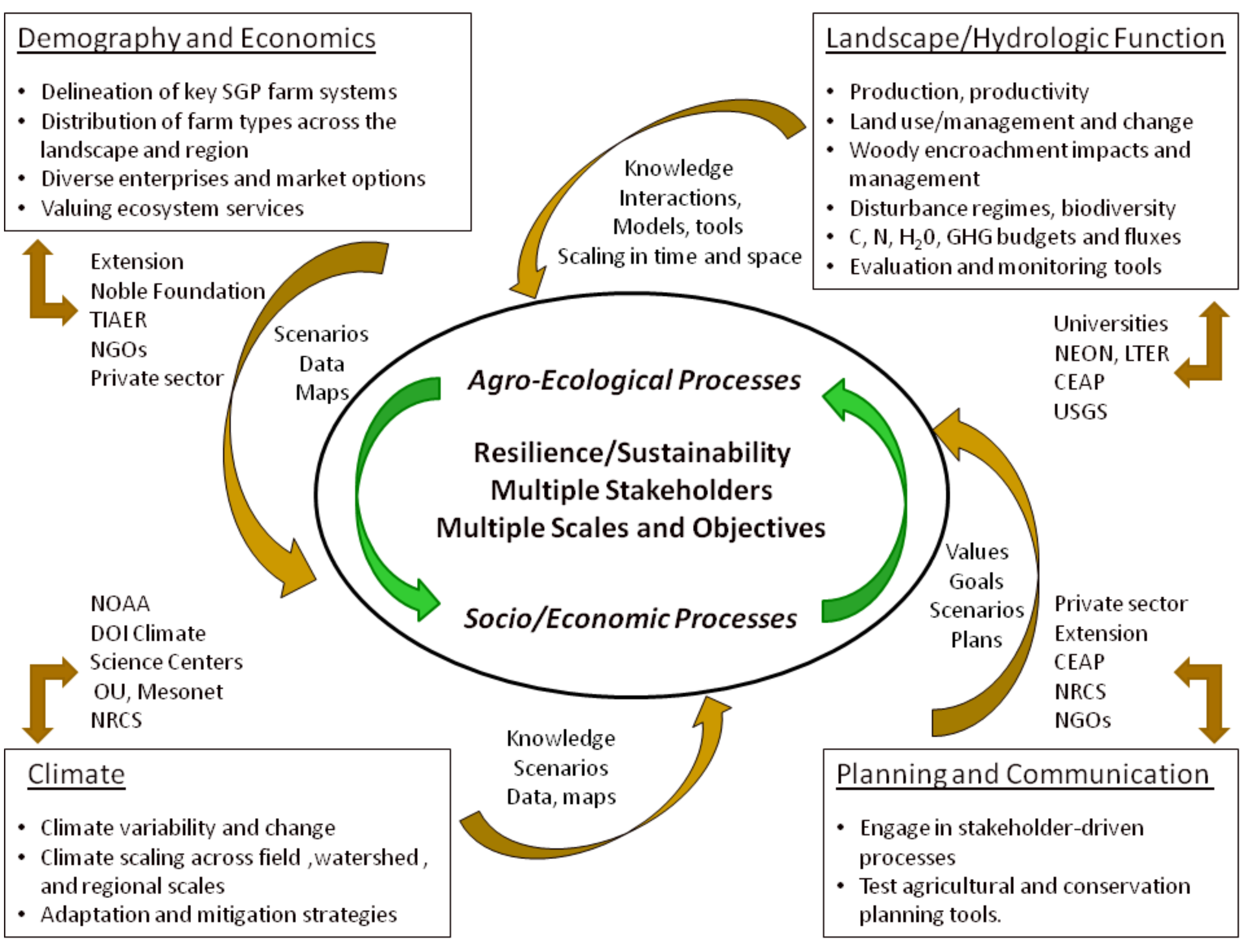


Long-Term Agro-Ecosystem Research
For the Southern Great Plains
USDA-ARS Grazinglands Research Laboratory Partnership
El Reno, Oklahoma



Resilience of Great Plains agricultural systems under variable climate conditions is essential. Research across the spectrum of cropland, pastureland, and prairie that is characteristic of the Great Plains is needed to identify sustainable forage-based production systems that are adaptable across enterprise types, from large-scale commercial livestock operations that dominate production and economics to small farms that dominate the landscape, particularly in the southeastern portions of the region. Anticipated research impacts include production systems that support vibrant rural economies, promote biological diversity (soil, plant, and animal), reduce greenhouse gas emissions, and increase soil organic matter, with corresponding positive impacts on carbon sequestration, water and air quality and agricultural sustainability. Developing knowledge and tools to support the diverse agricultural systems that comprise the fabric of the Southern Great Plains (SGP) landscape in the face of complex interactive climate, policy, and economics drivers requires transdisciplinary science conducted over decades to provide understanding that is scalable in time and space (Fig. 1).



Grazinglands Research Laboratory
El Reno, Oklahoma

November 15, 2011

Information provided
for consideration as affiliate of the

ARS Long-Term Agro-Ecosystem Research Network

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Rationale

Agriculture in the Southern Great Plains is mixed, with cropland, pastureland, and native prairie rangelands interspersed within individual farms and across the landscape. These lands and similar transitional lands between humid and arid zones in other parts of the world are important to global food security. Innovative production systems are needed to improve productivity while enhancing ecosystem function and ensuring profitability. Forage resources in this transition zone include both tall-grass prairie and introduced perennial grasses (e.g., Bermudagrass, yellow or old-world, bluestem), which provide resilience to summer forage supply during variable climate conditions. Winter wheat is the principal annual crop, with much of it serving dual-use as a cool-season annual forage as well as for grain production. Production from existing forage crops is, however, seasonal in nature and grazing livestock are confronted with significant periods of forage deficit throughout the year. Seasonal forage deficits are exacerbated by climate variability that include multi-year dry periods, so identification or development of plant materials and improved technology to provide improved quantity and quality of forage is essential.

With high prices for cereal grains, pasture production is being diverted to more marginal land with poorer quality soils, but the conservation requirements and potential for ecosystem services in these forage-grazing systems have not been well quantified. The prairie ecosystems are one of the most threatened of the U.S. ecosystems, due to historic conversion to cropland and pervasive encroachment of brush or woody species. Prescribed burning and chemical or mechanical control are the common mechanisms for maintenance or reclamation of brush- or tree-invaded grasslands, but burning and chemical control pose environmental concerns and mechanical control is expensive, unless some inherent value of the brush biomass could be recovered as biofuel. Managing ruminant livestock to improve or maintain the vegetative conditions has potential, but few long-term studies have been conducted to quantify impacts of managed grazing on both productivity and environmental services from native grasslands or from integrated crop-pasture systems.

The agricultural land use mosaic that is productive for livestock grazing also provides abundant ecosystem services including nutrient cycling, water filtration, and habitat for numerous at-risk avian, terrestrial, and aquatic species. Resource concerns of the southern Great Plains (SGP) cropland, pasture, and native rangeland landscape mosaic include soil degradation on cropland, wind and water erosion, sedimentation, leakage of nutrients from agriculture into aquatic systems, air quality impacts of agricultural burning and rangeland wildfires, vulnerability to climate variability and anticipated climate change, low productivity (e.g., highly eroded, former cropland abandoned or returned to grassland major droughts), invasion of brushy species, e.g., Eastern red cedar, mesquite, and unstable stream network (bank failure, gully erosion, headcuts).

Resilience of Great Plains agricultural systems under variable climate conditions is essential. Research across the spectrum of cropland, pastureland, and prairie that is characteristic of the Great Plains is needed to identify sustainable forage-based production systems adaptable across enterprise types, from large-scale commercial livestock operations to low-input and limited resource farms. Benefits may include production systems that enhance biological diversity (soil, plant, and animal) and that reduce greenhouse gas emissions and increase soil organic matter, with corresponding positive impacts on carbon sequestration, water and air quality. Forage materials and management practices that extend the productive grazing period of pastures and reduce the need for off-farm purchased inputs are needed to reduce costs of production, increase resilience of production systems under variable weather, and reduce economic risks.

Research and outreach capacity:

Major accomplishments:

- **TOPAZ** is a computer software package for automated analysis of digital landscape topographies in support of hydrologic modeling and analysis. TOPAZ identifies and measures topographic features, defines surface drainage, subdivides watersheds along drainage divides, quantifies the drainage network, and calculates representative subcatchment parameters. Particular emphasis is placed on maintaining consistency between all derived data, the initial input topography, and the physics underlying energy and water flux processes at the landscape surface.
- **SYNTOR climate generator**: Many watersheds lack sufficient weather data for long duration and continuous numerical simulation of watershed processes such as surface runoff, soil erosion, nutrient movement, sediment yield, and/or water quality. To enable such numerical simulations, available weather records must be augmented, transposed, or synthetically generated. SYNTOR is computer software that generates time-series of synthetic daily precipitation, daily minimum and maximum air temperature, and daily solar radiation for hydrologic and environmental investigations.
- **Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations**: Computer-based watershed models can save time and money because of their ability to perform long-term simulation of the effects of watershed processes and management activities on water quality, water quantity, and soil quality. These models also facilitate the simulation of various conservation program effects and aid policy design to mitigate water and soil quality degradation by determining suitable conservation programs for particular watersheds and agronomic settings. In order to use model outputs for tasks ranging from regulation to research, models should be scientifically sound, robust, and defensible (U.S. EPA, 2002). With this in mind ARS scientists from El Reno, OK, Temple, TX, Oxford, MS, and University Park, PA, established guidelines for model evaluation in order to guide modelers and model users. These guidelines have been used extensively worldwide and as of November 9, 2011, the manuscript has been cited 300 times since its publication in 2007.
- **STEWARDS data base development**: Comprehensive, long-term data from diverse watersheds are needed for hydrologic and ecosystem analysis and model development, calibration and validation. To support the Conservation Effects Assessment Project (CEAP) in assessing environmental impacts of USDA conservation programs and practices, researchers and staff from multiple ARS locations (El Reno, OK; Columbia, MO; Beltsville, MD; Ames, IA; Fort Collins, CP) developed a web-based data system: Sustaining the Earth's Watersheds, Agricultural Research Data System (STEWARDS). The data system organizes and documents soil, water, climate, land-management, and socio-economic data from multiple agricultural watersheds across the US and allows users to search, visualize, and download data. Anticipated benefits include preservation of data, increased data use, and facilitation of hydrological research within and across watersheds with diverse collaborators. (Steiner et al., 2008, 2009a, 2009b, ; Sadler et al., 2008)
- **Near-infrared reflectance spectroscopy (NIRS)** – Nutritional value of farm raised forages is important for producers to make management decisions concerning supplemental feeding of livestock. Conventional methods for analysis often take weeks to obtain at high labor costs. Scientists at GRL collaborated with a national network to develop and implement NIRS technology as a rapid, non-destructive method for analysis. This technology has greatly expanded the assessment of forages throughout the world (Coleman et al., 1985; Coleman and Murray, 1993).

- **Spectral analysis of forage quality traits**: Estimation of forage productivity and quality parameters during the growing season is important for adjusting stocking rate and making pasture management decisions. Remotely sensed data collected from ground, aircraft, or satellite platforms may be used to estimate grazing land productivity and forage quality. Scientists from our laboratory: 1) have demonstrated the feasibility of measuring selected forage quality parameters in situ and in real time using hand-held remote sensing devices; and 2) have demonstrated that such measurements can be used to determine the time in the grazing season when nutritional supplements should be given to free-grazing cattle (Starks et al., 2004; Starks et al., 2005; Starks et al., 2006b, 2006c; Phillips et al., 2007; Zhao et al., 2007; Starks et al., 2008; Starks and Brown, 2010).
- **Stocker cattle grazing system**: Dual purpose winter wheat is the primary forage in the Southern Great Plains grazed by 2mil stockers each year. Scientists at GRL developed resources and systems to fill gaps in the forage supply and extend the grazing season into early summer for an additional 200 kg gain per ha (Rao et al., 2002; Coleman et al., 2010).
- **Wheat Grazing model**: The Southern Greater Plains is the major winter wheat production region in US, and about half of the wheat acreage is grazed by cattle in winter. Scientists in GRL have developed a wheat grazing model for use as a decision support tool. The model has the potential to optimize grazing operations such as grazing density and initiation date as well as nitrogen fertilization rates according to initial soil moisture reserves, anticipated climate scenarios, and wheat and cattle market conditions.
- **Farm-finished beef** – Most of the stocker cattle that graze winter wheat in the southern Great Plains are finished in high capacity feedlots in the High Plains on high grain diets. Elevated grain prices have driven producers to find alternatives. Scientists at GRL evaluated low-capital farm-finishing methods that resulted in acceptable product quality and reduced grain input by up to 50% (Phillips et al., 2002; Kruse et al., 2008).
- **Use of Acoustic Profiling System and Rapid Geomorphic Assessment Methods to Provide Data for SWAT Calibration for Un-gauged Watersheds**: Well calibrated models are cost-effective tools used to quantify environmental benefits of conservation practices. However, sparsity of data to parameterize and evaluate models in many watersheds is the one of the main weaknesses. USDA ARS scientists in El Reno, OK and Temple, TX developed procedures that use 1) rapid geomorphic assessment (RGA) data to parameterize the stream channel network and 2) long-term average annual reservoir sedimentation rates data obtained during bathymetric surveys using the acoustic profiling system (APS) to evaluate sediment delivery rates simulated by watershed hydrologic models such as the Soil and Water Assessment Tool (SWAT) model. The results of a research conducted in southwestern Oklahoma using these procedures indicate that the RGA and APS techniques are potential cost-effective methods to obtain data to parameterize and evaluate watershed models in ungauged watersheds globally.
- **Applications of Seasonal Climate Forecasts**: Seasonal climate forecasts issued by NOAA's Climate Prediction Center appeared to offer a ready opportunity to develop climate-informed decision support for agricultural or water resource management. However, the probabilistic nature of the forecasts, the large forecast domains, the three-month period of each forecast, and the unknown forecast skill were significant impediments to their incorporation. Scientists at GRL evaluated the utility and dependability of the forecasts, revealing limitations in some regions of the U.S. including the Southern Great Plains, and for the entire U.S. during non-ENSO conditions (Schneider and Garbrecht, 2003, 2006, 2008);

- Created a methodology to translate the probabilistic seasonal climate forecasts into a form that can be used with crop and hydrologic models, and conducted research to demonstrate the methodology (Garbrecht et al., 2006; Garbrecht and Schneider, 2007; Garbrecht et al., 2010);
- Developed a downscaling technique to apply the forecasts to single locations or HUCs and monthly and daily scales (Schneider and Garbrecht, 2005).
- Evaluation of PRISM Precipitation Estimates: High quality and continuous monthly precipitation data for the 20th century is limited to a few hundred locations across the U.S., negatively impacting our ability to develop climate-informed decision support for agriculture or natural resource management. Scientists at GRL evaluated a gridded monthly precipitation product created at Oregon State University using the PRISM climate mapping system (www.prism.oregonstate.edu) against actual precipitation data from several sources in Oklahoma. The PRISM monthly precipitation climatology was shown to lack accuracy for months with relatively large total rainfall, and in higher order statistics such as variance and skewness (Schneider and Ford, 2011).

Process-based understanding

1. ***Impact of climate variability on hydrology and sediment yield in agricultural environments***: A good understanding of the interactions between climate change and the environment is essential to ensure a sustainable food supply for years to come, while at the same time maintaining agricultural soil and water resources for the next generation (Hatfield et al., 2011). Even though climate change occurs globally, impacts are regional and local, and must be studied at that scale. The SGP experienced a persistent pluvial period lasting most of the last quarter of the 20th century (Fig. 1) (Garbrecht and Rossel, 2002). However, this pluvial trend appeared to be declining in the first decade of the 21st century. Subsequent precipitation-runoff studies in the Oklahoma-Kansas region by Garbrecht et al. (2004) revealed a high sensitivity of watershed runoff and sediment yield to the observed multi-year pluvial-drought pattern. Thorough assessment of soil erosion, transport, and sediment yield at various spatial scales, for mixed land uses, and under a changing climate requires long-term, detailed, and concurrently measured watershed rainfall, runoff, and sediment yield data that are practically never available.

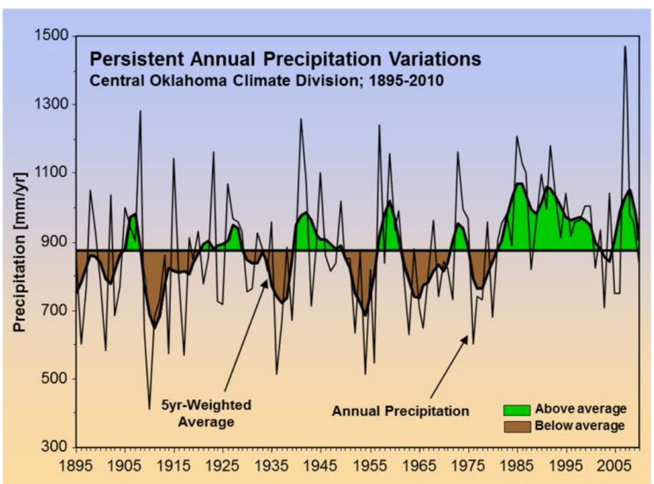

Figure 1. Persistent annual precipitation variations for central Oklahoma. 1895 to 2010.

2. **Improved understanding of soil water and energy fluxes**: Existing research networks and episodic field campaigns in the Southern Great Plains have been instrumental in development and assessment of new remote sensing technologies designed to provide regional measurements of soil water content (Jackson et al., 1999, 2005, 2010, 2011; Kustas et al, 1999; Bindlish et al., 2003; Oldak et al., 2003; Thoma et al., 2008). The proposed LTAR site has served as a test bed for comparison of techniques to estimate regional scale mass and energy fluxes (Anderson et al., 2008; Twine et al., 2000; Mohr et al., 2000; Kustas et al., 1999), and soil water

content data acquired within the proposed site have been used in assimilation studies to evaluate potential improvement in modeling soil water content deeper in the soil profile (Starks and Jackson, 2002; Heathman et al., 2003; Starks et al., 2003; Chen et al., 2011). The soil water content data from the proposed LTAR have also been used to determine if watershed scale soil moisture can be used to validate large foot-print satellite measurements of soil water content (Cosh et al., 2006; Starks et al., 2006a).

3. ***Assessing potential impact of climate change on water resources, soil erosion, and crop production***: it is fairly certain that global climate is warming. As a result, the frequency and magnitude of extreme events such as drought and flood will increase. It is extremely important to assess the potential impact of climate change on soil erosion and crop production at particular locations in different physiographic regions, so that proper mitigation and adaptation measures can be developed for the locations. Scientists in GRL have developed a temporal and spatial downscaling method for assessing those impacts for specific locations using hydrological and crop models.

4. Grassland ecosystems

a. *Impacts of grazing on soil nutrient cycling, vegetation diversity, and grass and animal productivity.* Resilience of Great Plains agricultural systems under variable climate conditions is essential. Forage production is likely to be diverted to more marginal land with soil and climatic limitations because of land-use conversions caused by raising prices for feed grains, increasing global demand for livestock products, and the prospects of large areas of land being converted into biofeedstock production. Research at GRL will involve the spectrum of cropland, pastureland, and prairie that is characteristic of the Great Plains, and will identify sustainable forage-based production systems that offer a range of plant materials and management techniques adaptable across enterprise types, from large-scale commercial livestock operations to low-input and limited resource farms. Future production systems must enhance biological diversity (soil, plant, and animal), reduce greenhouse gas emissions, and increase soil organic matter, with corresponding positive impacts on carbon sequestration, water and air quality. Forage materials and management practices that extend the productive grazing period of pastures and reduce the need for off-farm purchased inputs, will reduce costs of production, increase resilience of production systems under variable weather, and reduce economic risks.

b. Impacts of Eastern redcedar in native grasslands on soil nutrients and water balance
Eastern redcedar is a native tree that has encroached upon millions of hectares of range and grasslands in the SGP, due in large part to reduction of natural prairie fires, overgrazing, and absentee land ownership. This encroachment reduces forage availability, degrades wildlife habitat, increases wildfire potential, and has been implicated in reductions of surface runoff and groundwater recharge. Removal of redcedar from the landscape is a high priority grassland conservation practice, and redcedar is being considered as a possible biofuel/bioenergy source. Remote sensing experiments were conducted to assess the above ground dry mass of redcedar (Starks et al., 2011) to help support rural industries using redcedar as a commercial and/or bioenergy product.

The impacts of redcedar on local and regional hydrology, carbon storage, and soil physical, hydrologic, and chemical properties is being investigated to develop strategies to improve range and grassland condition on lands where redcedar will be harvested or cleared from the landscape. Experiments are being planned to address these issues and to inform ecological state and transition models.

2) **Infrastructure Capacity**

The Grazinglands Research Laboratory (GRL) includes the Forage and Livestock Production Unit and the Great Plains Agroclimate and Natural Resources Unit. The GRL research is part of National Programs (NP) in Water Availability and Watershed Management; Pasture and Forage and Rangeland Systems; Food Animal Production; and contributes to goals of the Global Change, Soils, and Emissions NP; Bioenergy NP, and others. In 2010, the GRL, in collaboration with the Office of National Programs and Southern Plains Area leadership, convened a Visioning Conference to thoughtfully consider the highest priority research and technology needs to which laboratory resources should be devoted. A goal of the Visioning Conference and key recommendation of the Science Synthesis Team was greater integration and leverage across research units which address water resources and livestock-grazing systems issues. Through the process of NP Customer Workshops, development of NP Action Plans, and development of new GRL project objectives, the recommendations of the Visioning Conference are being implemented. The Grazinglands Research Laboratory (GRL) research projects address concerns related to agricultural productivity and ecosystem function within the SGP, but the issues and research findings are of global significance. Because of the comprehensive research program, the long-term research record, and the in-house capacity of GRL, numerous partners have reached out for new or broadened collaborative efforts.

T he Conservation Effects Assessment Project (CEAP) is a multifaceted project that was developed to provide understanding and quantitative measurements of agricultural conservation at a watershed scale (Richardson et al. 2008). In 2003, long-term watershed search in the Washita River basin became a part of the croplands CEAP (Steiner et al., 2008) and in current research, objectives of Grazing Land CEAP are also being addressed.

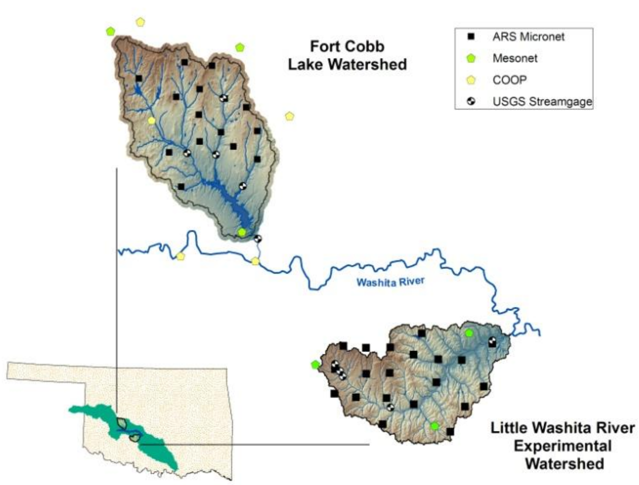

Figure 2. Location of the Little Washita River and Fort Cobb Reservoir experimental watersheds.

The Upper Washita River hydrologic unit is an 8,319-km^2 area in west central Oklahoma, with agricultural systems and environmental issues that are typical in the southern Great Plains. The USDA Agricultural Research Service (ARS) has conducted watershed research in the Upper Washita River Basin since 1961 (Garbrecht et al. 2007), particularly in the Little Washita River Experimental Watershed (LWREW). In 2004, the research facility was expanded to include the Fort Cobb Reservoir Experimental Watershed (FCREW) as part of the CEAP watershed assessment studies (Fig. 2). The FCREW was selected for in-depth study because it had been identified by the Oklahoma Water Resources Board, Oklahoma Department of Environmental Quality, and Oklahoma Conservation Commission as a focal point to apply land conservation practices in order to improve water quality (Oklahoma Water Resources Board 2003; Storm et al. 2003; Steiner et al. 2004). The Fort Cobb Reservoir and its watershed had been the focus of monitoring and assessments for several years, thus providing baseline data against which future environmental conditions could be assessed (e.g., Becker 2001; Fairchild et al. 2004).

The Upper Washita River CEAP watersheds are strategically positioned between additional CEAP watersheds that focus on mixed agricultural land use and grazing land issues, with the Cheney Lake, KS; Upper Washita River, (Fort Cobb and Little Washita), OK; Leon River, and North Bosque River watersheds, TX located along the ~100th parallel longitude, providing capacity for scaling from watershed to regional scale.

3) **Data Richness**

<u>Watershed data (1961 to present)</u>
The Southern Great Plains Research Watershed (SGPRW, 1130 sq. mi.), the LWREW (236 sq. mi.), the FCREW (304 sq. mi.), and the 8 Water Runoff and Erosion watersheds (WRE, 5 ac. each) are located in south-central Oklahoma. The climate is sub-humid, and average annual rainfall is around 33 inches. Physiographic characteristics are typical of the Rolling Red Plains of western Oklahoma. A wide range of hydrological variables have been collected dating back to 1961. Data include primarily rainfall, weather variables, groundcover, soil erosion, stream flow, sediment yield, and water quality at plot, field, watershed, and landscape scales. Below are listed the instrumentation and duration of records for each of the four watersheds. Most of the collected data were quality controlled. Occasional short gaps exist in the data records due to instrument malfunction, repair, or scheduled servicing, otherwise data are relatively complete. Configuration of watershed instrumentation has changed over time as dictated by programmatic research emphases.

- *Southern Great Plains Research Watershed (time period 1961-1978)*
  - Daily rainfall at up to 230 rain gauges
  - Weather variables at 2 climate stations
  - Discharge and sediment at 15 stream gauges on 11 watersheds
  - Discharge and sediment at 6 stream gauges on the Washita River
  - Event based runoff and water quality at 22 small unit-source watersheds
  - Groundwater table 88 groundwater observation wells
- *Little Washita River Experimental Watershed (various configurations)*
  1961-1985
  - Daily rainfall at 36 rain gauges
  - Discharge and sediment at 2 stream gauging stations
  - Water quality and groundwater level at 24 groundwater observation wells
  - Event based runoff and water quality at 11 unit source area watersheds

  1985-1992
  - Daily rainfall at 14 rain gauges
  - 1 stream gauging station on a tributary to the Little Washita River
  - Runoff and sediment at 2 unit source area watersheds, discontinued in 1989

  1992-2004
  - Rainfall, temp, humidity, solar radiation, and soil temp) at 42 Micronet stations
  - Same as above plus wind variables at 3 Mesonet climate stations
  - Discharge at up to 7 stream gauging stations on Little Washita River watershed
  - Reservoir levels at 3 reservoir-pool gauging stations

  2004-present
  - Suite of weather variables at 22 Micronet climate stations
  - Reservoir levels at 1 reservoir-pool elevation gauge

- Discharge at 4 stream gauging stations

GIS Data layers

- NRCS Soils (STATSGO and SURGO)
- 10 meter Digital Elevation Model
- 2005 Landuse derived from Landsat

- *Fort Cobb Reservoir Experimental Watershed (time period 2004-present)*
  - Suite of weather variables at 3 Mesonet climate stations
  - Daily rainfall at 4 NWS Cooperative Weather Stations
  - Suite of weather variables at 15 Micronet climate stations
  - Discharge at 1 stream gauge on Cobb Creek
  - Discharge and sediment at 4 stream gauges on tributaries to Cobb Creek
  - Grab samples every two weeks at 17 locations for stream water quality
- *Water Resources and Erosion Watersheds (time period 1976-present)*
  - 8 water resources and erosion unit source watersheds
  - Rainfall at 4 rain gages
  - Event based discharge, sediment and water quality at 8 runoff flumes
  - Groundwater levels at 24 wells
  - Records of soil properties and profiles, and soil moisture
  - Records of land management, agronomic practices, stocking rates, crop yields

Grazinglands Research Laboratory (1948-present)

The USDA-ARS GRL was established in 1948 on a former U.S. Cavalry remount station known as Fort Reno. The GRL is located about 45 km west of Oklahoma City, OK (35^{o} 33'N 98^{o} 02'W) within the central Rolling Red Prairie geomorphic province. The GRL is situated in the transition zone between tallgrass prairie to the east and mixed grass prairie to the west. The prevailing native vegetation is defined as southern tallgrass prairie, often reaching 1 to 3 m in height. Depending on growing conditions, 60 to 90% of annual herbaceous production is by warm season tallgrasses [big bluestem (Andropogon gerardii), indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum)], and the mixed grass little bluestem (Schizachyrium scoparium). The most-common perennial cool-season grasses include western wheatgrass (Elymus smithii), Canada wildrye (Elymus canadensis) and Scribner's panicum (Panicum oligosanthes). Farming within the region is largely dryland with conventional tillage practices the norm, but interest in conservation tillage is increasing. The 2,711 ha of land at GRL are planted in a variety of forages including: native prairie (1,214 ha), wheat (365 ha), improved grass varieties (809 ha), and numerous experimental plots of cool and warm season perennial and annual grasses and legumes. The most common soil types on GRL are silty-clay loams on crests and side slopes of hills that developed on the Permian-age Dog Creek shale formation. Long-term research records include weekday precipitation data collected at 8 sites scattered across GRL from 1982 through 2009; this data has been quality assured and archived. Distribution of precipitation has been generally bimodal with peaks in April-May and September-October, although the seasonality of precipitation has been shifting recently. Moderate to severe droughts are common, and can persist for several years. The frost-free growing season has varied from 179 to 249 days, with an average of 219 days. A brief accounting of land and animal management at the GRL is given below. (See Appendix C for GRL map).

1948-1984

- Native pastures (All) were continuously grazed with cattle. Breeding herds were maintained at 4 ha/cow-calf unit on west side and 3.2 ha/cow-calf unit on east side. Fields 26, 84, and 41-48 were farmed to wheat, alfalfa, corn and sorghum.

1982-2009

- Wheat barn pastures (41,42,45,48) – Planted to wheat continuously and grazed with cattle during fall and winter. Grain was harvested some years, but primarily used as grazeout (through May). Stocking density and animal gain available for most years (in publications). Some plant biomass and quality data available.

1982-1999

- Big bottom (84) – Planted to wheat continuously and grazed by cattle during fall and winter. Some grain harvest, but most years used for grazeout. Intensive data collection from 1982-1990 that included animal performance, stocking rate, herbage mass and quality. Soil data collected in 2000 prior to establishment of cool-season perennial pastures.

2000-present

- Big bottom (84) was subdivided into 15-acre blocks (2001) and planted to a variety of C3 perennial pastures with some planted to wheat. All were grazed annually at various times to develop annual/perennial system for extended grazing. Annual data for animal performance, stocking rate, herbage mass and quality, and soil C & N status (2001& 05) were monitored in a subset of pastures.

1985-1995

- Bermuda bottom (86, 88, & 89) was grazed by stockers for summer animal production with stocking rate, animal performance, herbage biomass and quality data available.

1980-1999

- Old-world bluestem (28) were grazed during summer grazing with stocker calves. Some years (1980-1989) very data rich (available in publications and electronic files upon request) including animal stocking rate, performance, eating behavior, intake, diet quality, herbage mass and characteristics. Other years (1995-1999) included supplementation with similar data richness. Currently being farmed with summer annuals.

1993-1998

- Old-world bluestem (11) was used for year round grazing (cow-calf) and haying. Set stocking with 2-pasture rotation/haying. Animal performance data available.

1993-1998

- Native prairie (9, 10, 13, 14) was used for year-round grazing with cow-calf. Comparison of continuous and 4-pasture rotation. Range assessment before and after. Animal performance data available.

2001-2009

- Native prairie (12, 17) was grazed in winter with stocker cattle part time as alternative to continuous wheat pasture. Animal data and stocking rate in publications.

2005-2006

- Native pastures (13) assessed for carbon dynamics due to prescribed burning. Pre-burn biomass and below ground assessment made in Mar 05. Eddy correlation data collected from Mar 05-Apr 06; also, biomass and below ground assessment made annually.

2008-present

- Native pastures (East side - holistic grazing) – grazing system comparison with cow-calf as the animal unit. Continuous compared to rotational grazing. Monthly measurements of biomass, animal density, and weight change. Below ground assessment made at commencement. Data collection in progress.

Other

- Ongoing regional remote sensing/hydrology experiments designed to develop and test systems and algorithms for determination of soil water content and regional fluxes of energy and mass

(e.g., Washita 92, Washita 94, SGP 97, SMEX03, CLASIC), with most of the data from these experiments publically available from various websites.
- The Oklahoma Mesonet (www.mesonet.org/index.php/site/about), with 120 environmental monitoring stations covering Oklahoma, producing data every 5 minutes that is automatically transmitted, recorded, extensively quality controlled, archived and available online, for 1993 through the present; the El Reno Mesonet site is located at GRL.
- The DOE ARM Climate Research Facility, Southern Great Plains Site (http://www.arm.gov/sites/sgp), with environmental measurement sites across southern Kansas and northern Oklahoma, obtaining continuous field measurements and providing data products including critical components of the water and energy budgets of the atmosphere and land surface; quality assured archived data is available online for 1993 through the present; the extended facility at GRL was discontinued after tornado damage in 2011.
- Several Global Energy and Water Cycle Experiement (GEWEX) Projects included extensive observational data from the Southern Great Plains, and are summarized in various GEWEX data products (www.gewex.org); the GEWEX program is a core project of the World Climate Research Programme.
- The NRCS SCAN program (www.wcc.nrcs.usda.gov/scan/) operates on site at the GRL and one site on the Little Washita River experimental watershed, both reporting since November 1998.

4) **Data Availability (Accessibility)**
- STEWARDS (Little Washita data published/update in process; Fort Cobb data submitted/in revision)
- Agreement established with OSU in 2011 to assist with development of GRL data management framework to better interface with national networks. Inventory of GRL forage and grazing data for digitization is underway.
- Ongoing regional remote sensing/hydrology experiments designed to develop and test systems and algorithms for determination of soil water content and regional fluxes of energy and mass (e.g., Washita 92, Washita 94, SGP 97, SMEX03, CLASIC), with most of the data from these experiments publically available from various websites.
- Meterological data (1994 to present) from our distributed measurement network (the ARS Micronet) on the proposed LTAR is publically available via our website. Meteorological and stream runoff data prior to 1994 are accessible via ftp access.
- Agronomic and animal production data from GRL are largely in journal articles and field day reports. More recent data could be made available in electronic form. The GRL has initiated an effort to develop an electronic data management system for current and historic land management and field research records.
- Oklahoma Mesonet and DOE ARM Climate Research Facility data are described in detail, and are publically available online.
- NOAA's radar-based daily precipitation analysis data covers the Southern Great Plains at 4-km resolution (water.weather.gov/precip/), and is described and publically available online.

5) **Geographic Coverage at Various Scales**
The proposed site is within the Southern Great Plains Major Agro-ecosystem and addresses key questions regarding the sustainability of wheat, forage, prairie, cattle, and ruminant grazing systems. The proposed site is also situated at the convergence of several ecosystems (Bailey, 1995; Fig. 3). The site is located in the Arkansas-White-Red Hydrologic Unit with research locations spanning the Red River (Little Washita River, Fort Cobb Reservoir, and Upper Washita River watershed sites) and the Arkansas

River basins (Grazinglands Research Laboratory is bounded by the North Canadian River; a planned watershed study will extend from Canton Lake to Lake Overhouser on the North Canadian River to address questions of hydrologic impacts of Eastern redcedar into native vegetation. This study stream reach is a major water supply to Oklahoma City Public Utility). The research watersheds and laboratory are located in NEON's Southern Plains region. Ecological Site Description research for Southern to Central Plains is planned under NP215. The proposed site is situated within a strong precipitation gradient (west to east) and thus represents a transition zone from the arid west to the humid southeast which experiences large variations in weather conditions from year to year.

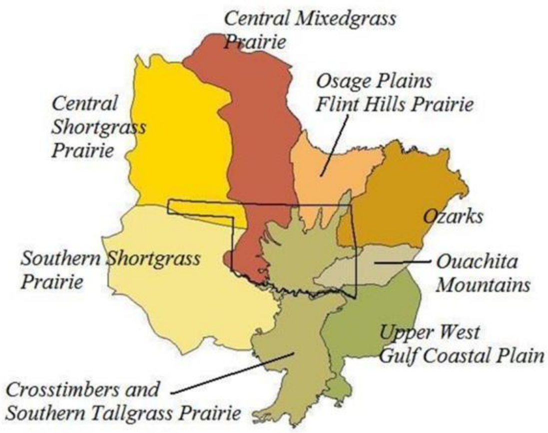

Figure 3. Location of the proposed site in relation to Bailey's (1995) ecoregions.

Note that the nested co-location of the GRL observation networks within the Oklahoma Mesonet and DOE ARM Climate Research Facility offers an opportunity to geographically scale many of the key variables in energy and water transport at the land surface. The availability of NOAA/NWS daily gridded precipitation data across the Southern Great Plains provides a critical fine-scale data source to anchor all future modeling efforts. The research potential of these nested networks has yet to be realized in any significant sense.

6) **Partnerships**

Agreements support collaboration as follow:

- Oklahoma State University – Mesonet SCA supports the ARS Micronet and fosters a range of climate-related collaborations.
- Oklahoma Water Resources Board and USGS SCA focuses on stream gauging and water quality research in CEAP watersheds.
- Tarleton State University SCA focuses on scaling from farm to watershed scale, economic assessments, and environmental and economic tradeoff assessment.
- Noble Foundation agreement focuses on intergrated systems forage-grazing research.
- Unversidad Autonoma de Zacatecas agreement focuses groundwater sustainability. This SCA includes collaboration with the Ogallala Project, Texas A&M, and University of Georgia.
- Oklahoma State University Biosystems and Agricultural Engineering SCAs has supported a wide range of activities related to SWAT modeling, data base development, erosion modeling.

- Research –
  - CEAP research in the Fort Cobb Reservoir watershed was designed to address conservation priorities of the Oklahoma Conservation Commission, Oklahoma NRCS, and farmers and ranchers in the watershed.
  - GRL scientists are collaborating with USGS Oklahoma Water Science Centers on research proposals to address regional surface and ground water issues. This builds on

collaboration in the CEAP Fort Cobb watershed funded through the USGS Collaborative Science Program

- The Laboratory is a partner to the DOI South Central Climate Science Center, recently awarded to the University of Oklahoma-led consortium.
- The proposed site also hosted one of the DoE's ARM/CART Extended Facilities from 1997 to 2011 (due to budget cuts the DoE is scaling back its ARM/CART program to a smaller portin of Oklahoma and Kansas, but the data from the program should be publically available for some time to come)
- The proposed research site has hosted numerous remote sensing/hydrology experiments that have included participation from other ARS labs, numerous US universities, and other research agencies both within and outside the US (too numerous to list here)
- The proposed site has conducted and is conducting various genetic by environment interactions studies which require participation of cattle producers from various parts of the US.
- The DoE has conducted short-term (2005-2006) carbon studies on the grasslands of the proposed site.
- The proposed research site hosts several both a permanent Mesonet measurement system, and intermittently hosts temporary systems for field programs, as part of the 120 -site meteorological distributed throughout the state of Oklahoma.
- The synthetic weather generation research for seasonal forecasts and climate change is conducted in collaboration with the NRCS Water Quality and Quantity Development Team of the West National Support Center in Portland, OR.
- Research on soil and water conservation needs under anticipated climate change in the Southern Great Plains of the United States.
- Research on management and sustainable utilization of groundwater resources in agricultural watersheds that rely heavily on groundwater as a source of irrigation water.
- Dr. Zhang has collaborated with scientists from the Institute of Soil and Water Conservation, Chinese Academy of Sciences (Yangling, Shaanxi, China) in the past several years to evaluate the potential impacts of climate change on soil erosion and water resources in the Loess Plateau of China and central Oklahoma.
- Zhang is currently working with professors of Beijing Normal University (Beijing) to track sediment sources and to estimate soil erosion and reservoir sedimentation rates using radionuclides of ^{137}Cs and ^{210}Pb and geochemicals in the Fort Cobb watershed.
- The proposed research site collaborates with the ARS Lab in Temple, Texas on the development of SWAT, specifically addition of new tile drain and water table depth algorithms available to users in different regions.
- The proposed research site collaborates with the ARS Lab in Temple, TX, ARS Lab in Bushland, TX, and Texas A&M University to develop the sequentially linked EB_ET-SWAT-MODFLOW model system. The linked model would account for all major hydrologic processes above, on, or below the land surface.
- The proposed research site collaborates with Kenyan scientists through the UNESCO HELP twinning pilot project entitled "Fort Cobb Reservoir Watershed, Oklahoma and Thika River Watershed, Kenya twinning pilot project". This project seeks to assess the current reservoir sedimentation status and to determine conservation practices that will

    - minimize watershed erosion and reservoir sedimentation to ensure sufficient water resources for the growing populations under projected long-term climate change in Kenya.
    - The proposed research site collaborates with ARS CPRL in Bushland, TX, several US universities, and Mexican scientists on a USAID project entitled "A Decision Support System for the Sustainability of the Calera Aquifer in Zacatecas, Mexico". The overall goal is to develop a technological tool to provide better decision support to the many organizations and individuals who must develop and implement policy to reduce groundwater depletion in both regions and countries and to foster stronger international relationships.
    - several both a permanent Mesonet measurement system, and intermittently hosts temporary systems which are afor field programs, as
- Education –
    - Research scientists serve as adjunct faculty at Oklahoma State University and University of Arkansas on graduate committees and numerous graduate students have conducted their research at GRL in collaboration with ARS scientists.
    - Under the collaboration framework, Zhang has hosted one visiting scientist from China (9 months) and a joint-training Ph.D. student from China (2 years). We are currently providing partial financial support to a Ph.D. student at the OSU-Dept. of ABE to track sediment sources in the Fort Cobb watershed.
    - Moriasi served on one Master's thesis committee at University of Zacatecas, Mexico.
    - Starks has served on two Master's thesis committees, one at the University of Oklahoma, and one at Oklahoma State University.
    - Schneider and Ford are mentoring an undergraduate student in ongoing research on gridded precipitation products as part of the NIH Bridges to Baccalaureate Program in collaboration with Redlands Community College (El Reno, OK) and East Central University (Ada, OK).
    - Several visiting scientists (1 Chinese, 1 Mexican, 1 ARS Bushland, 1 Texas AgriLife, Texas A&M) and one student (University of Texas at San Antonio, TX) have received training on building and calibrating SWAT model projects.

- Outreach –
    - The laboratory director serves as an ex officio member of the Oklahoma Grazing Lands Conservation Initiative and on the NRCS State Technical Committee.
    - The research meteorologist:
        - serves as an invited advisor for the Southern Climate Impacts Planning Program (SCIPP), a joint University of Oklahoma and Louisiana State University effort (http://www.southernclimate.org/about.php). SCIPP is the ninth and newest Regional Integrated Sciences and Assessments (RISA) program supported by the Climate Program Office at the National Oceanic and Atmospheric Administration;
        - reviews proposals for the NOAA RISA program; and
        - was invited to represent agricultural interests for a NOAA/Office of Hydrology stakeholder workshop.

7) **Institutional Commitment**—See Appendix B for Letter of Support from Dr. Dan Upchurch, Area Direction, Southern Plains Area.

Examples of areas where scientists in both research units at the GRL are engaged in cross-unit research

- Impact of redcedar on hydrology and on forage and rangeland recovery.
- Remote sensing of natural resources, including forage biomass and quality, and animal intake.
- Impact of climate variability on forage and rangeland ecosystems.

Additional Factors That Could Enhance the Case for a Specific Site

- Two NRCS Soil Climate Analysis Network (SCAN) sites are located in the proposed site, one on the GRL grounds, and one on the LWREW.
- The GRL was invited by OSU PD to serve as co-PD for an AFRI-CAP proposal focused on SGP mixed-land use forage-grazing systems, entitled "Resilience and vulnerability of beef cattle production in the Southern Great Plains under changing climate, land use and market" (in process).
- The proposed site is nested within the state-wide Mesonet meteorological network (120 stations) and within DoE's Southern Great Plains ARM/CART network.

Commitment to Responsibilities of LTAR Network Sites

The leadership and science team of the Grazinglands Research Laboratory agree to meet the responsibilities of working toward common goals with shared protocols, quality standards, and data sharing; attending LTAR meetings and workshops; undergoing review; and welcoming research partners from other locations and institutions to join in the research planning and execution processes.

Summary

The GRL has extensive capacity for agro-ecological research, focused on forage grazing systems, at field and watershed scales. At the field scale we have a 250 head cow-calf herd, sheep flocks, animal handling and research facilities for all phases of the dominant beef-production system, including instrumented research feedlots, comprehensive field operations equipment, modern greenhouse, comprehensive laboratory facilities, and instrumented unit-source watersheds. At the watershed scale we have the FCREW which represents traditional mixed agricultural cropping watershed, while the LWREW represents predominantly grazingland agriculture. We believe that our research staff and facilities, together with our current and historic data bases, and strong research collaborations with other partner laboratories located across the Great Plains gradient, make us strong candidates for inclusion in ARS' proposed LTAR network.

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Appendix A. Scientific Staff

Jean L. Steiner, Laboratory Director

Great Plains Agroclimate and Natural Resources Research Unit

Jurgen D. Garbrecht, Lead Scientist	Hydraulic Engineer
Daniel N. Moriasi	Hydrologist
Jeanne M. Schneider	Meteorologist
Patrick J. Starks, Lead Scientist	Soil Scientist, Remote Sensing
Jean L. Steiner, Research Leader	Soil Scientist
Xunchang (John) Zhang	Hydrologist
Jorge Guzman, Research Associate	Hydrologist

Forage and Livestock Production Research Unit

Paul Bartholomew, Lead Scientist	Forage Agronomist
Samuel C. Coleman, Research Leader	Animal Scientist
Bryan Kindiger	Plant Geneticist
James Neel	Animal Scientist
Brian Northup	Ecologist
Srinivas Rao	Legume Agronomist
Kenneth Turner	Animal Scientist

Appendix B. Southern Plains Area Director Support

November 9, 2011

To Whom It May Concern:

I am writing to indicate institutional support for inclusion of the Grazingland Research Laboratory (GRL), in the USDA-ARS Long Term Agricultural Research (LTAR) network. With the extensive long-term watershed and grazing research capacity, the broad-interdisciplinary research program, and numerous research partners, this is the exact type of location that I would expect to be a part of the LTAR.

In particular, GRL's Great Plains Agroclimate and Natural Resources unit has been conducting research in the Little Washita River (LWR) and other portions of the Washita River Basin since 1961, including addition of the Fort Cobb Reservoir (FCR) watershed as a Croplands CEAP site since 2004. The unit contributed substantially to development of the STEWARDS data system, has published the Little Washita River data on STEWARDS, and is preparing Little Washita River updates and Fort Cobb Reservoir submission. The research includes a dense climatological monitoring network in the LWR and FCR watershed that is an integral part of the Oklahoma Mesonet. The Oklahoma Mesonet also maintains a meteorological station on the GRL property, and data from all the ARS Micronet and Oklahoma Mesonet are online real-time, as is all stream gauging monitoring supported collaboratively by ARS, USGS, and the Oklahoma Water Resources Board.

The Forage and Livestock Research Unit has conducted forage, livestock, and grazing research on the 2700–ha property since 1948, initially through an ONP-led agreement with the Oklahoma State University and since 1970 with ARS research staff. On the research property there are large fields and paddocks with numerous native prairie pastures, introduced-perennial species pastures, and grazed winter wheat, all with known management records going back decades.

In 2010, the GRL, in collaboration with the Office of National Programs and Southern Plains Area leadership, convened a Visioning Conference to thoughtfully consider the highest priority research and technology needs to which laboratory resources should be devoted. A goal of the Visioning Conference and key recommendation of the Science Synthesis Team was greater integration and leverage across research units which address water resources and livestock-grazing systems issues. Through the process of NP Customer Workshops, development of NP Action Plans, and development of new GRL project objectives, the recommendations of the Visioning Conference are being implemented. The Grazinglands Research Laboratory (GRL) research projects address concerns related to agricultural productivity and ecosystem function within the SGP, but the issues and research findings are of global significance. With their history and forward visioning, the GRL is certain to be a long-term fixture in plans of ARS.

Sincerely,

Dan R. Upchurch, PhD
Director, Southern Plains Area

Appendix C. Map of the Grazinglands Research Laboratory