SOUTHEASTERN COASTAL PLAIN LTAR APPLICATION: LITTLE RIVER EXPERIMENTAL WATERSHED

SOUTHEAST WATERSHED RESEARCH LABORATORY, TIFTON, GA

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INTRODUCTION: As directed by Senate Document 59 (U.S. Congress, 1959), the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) established regional watershed hydrology research centers across the nation in the 1960s. Each regional watershed center was located to address specific research needs and important natural resource and environmental issues at the watershed scale within major land resource areas. Experimental watersheds were instrumented at each of the centers to serve as outdoor laboratories providing field data required for conducting scientific investigations aimed at developing a greater understanding of hydrologic processes. The Gulf-Atlantic Coastal Plain physiographic region, an important agricultural production area within the southeastern U.S., was identified in 1965 as a priority location for a regional hydrology research center. The region extends from Delaware in the Northeast to the Gulf Coast of Texas. The region consists mainly of low-elevation flat to rolling terrain with numerous streams, abundant rainfall, a complex coastline, and many wetlands. The irregular, relatively flat plains of the region are covered by a mixture of cropland, pasture, forest, and wetlands. The region is characterized by long growing seasons. Natural forests of pine, hickory, and oak once covered most of the region, but much of the natural forest cover has been replaced by heavily managed timberlands. Streams throughout the ecoregion are relatively low gradient and sandy bottom.

The Southeast Watershed Research Laboratory (SEWRL) was established later in 1965 and the Little River in south-central Georgia, U.S. was subsequently selected as the primary field research site. The Little River was considered to be generally representative of the climate, topography, soils, geology, stream networks, and agricultural production systems within the Level III Southeastern Plains ecoregion. Additionally, the contribution of surface water to deep seepage was believed to be relatively small, simplifying defining experimental watershed water budgets. The Little River Experimental Watershed (LREW) is in the headwaters of the Suwannee River Basin, a major interstate basin that begins in Georgia and empties into the Gulf of Mexico in the Big Bend region of Florida. The Suwannee River Basin is completely contained in the Coastal Plain Physiographic Region and is the largest free-flowing river in the Southeastern Plains. The Suwannee is one of only twelve EPA national showcase watersheds. The relatively undeveloped watershed allows for an unprecedented opportunity to characterize how a relatively unimpacted watershed will respond to increasing urbanization, water demand, and other anthropogenic stresses. The LREW is operated by the USDA Agricultural Research Service Southeast Watershed Research Laboratory (SEWRL) in Tifton, GA where records on precipitation, soil moisture, and climate data are maintained in the LREW database (**ftp://www.tiftonars.org/**).

The 334 km^2 LREW originates approximately 9.6 km west of Ashburn, Georgia near the northwest corner of Turner County. The watershed flows in a generally southerly direction to its confluence with the Withlacoochee River, eventually joining the Suwannee River in north Florida. The LREW is in an area of broad floodplains, river terraces, and gently sloping uplands. Moderately wide interstream divides separate relatively broad valleys. The watershed is located on sandy soils underlain by by a Miocene age sandstone (the Hawthorn Formation) which is underlain by limestones that form the Floridan Aquifers. Locally the Floridan aquifers are confined and stream networks are generally not incised into deeper groundwater aquifers. A seasonally dependent shallow aquifer exists throughout the watershed that drains into the stream network. The upland watershed divides are nearly level, very gently sloping or undulating. Valley bottoms are nearly level and valley sides are gently sloping. Most slopes are less than 5%, although some valley side slopes range from 5 to 15%. Flow characteristics from these watersheds have been shown to be similar to many parts of the Coastal Plain region where the aquifer system is confined or semi-confined (Sheridan, 1997). Water yield is typically higher on a per unit area basis than that observed from many other areas in the U.S. Nutrient budgets for LREW were among the first ever published for mixed cover agricultural watershed and showed the importance of land use and nutrient retention processes (Lowrance et al., 1985).

HISTORY OF PRODUCTIVITY: Eight hundred and forty-six peer reviewed journal articles and graduate student theses have been published by scientists during their tenure at the Southeast Watershed Research

Laboratory. Scientists currently working at the lab have produced 432 of those manuscripts. The SEWRL historical bibliography can be accessed from the unit's web site at: http://www.ars.usda.gov/Main/site_main.htm?modecode=66-02-05-00. Using the LREW, SEWRL scientists have been responsible for many important research discoveries. A sample of these include:

Quantifying hydrologic characteristics for Coastal Plain Watersheds. Research at the LREW has provided a conceptual understanding of hydrologic flow processes on Coastal Plain Watersheds. Studies have documented the proportioning of surface and subsurface movement of water from upland areas, thereby indicating the importance of subsurface flow on nutrient transport from upland agricultural areas, and at a larger scale, on watersheds with poorly-drained, low-gradient stream systems. The role of watershed physical characteristics on hydrologic response as well as on the seasonal nature of Coastal Plain watershed storm response characteristics has been well documented. This work directly addresses original objectives specified at the inception of the watershed research program and establishment of the LREW. Natural Resource Conservation Service hydrologic design procedures have been evaluated and improved methodologies and procedures developed for estimating agricultural drainage and storm runoff volumes for use in design and modelling applications on poorly-drained, flatland watersheds. The LREW data have been used in development of water yield and water balance information, hydrologic and water quality budgets, and rainfall-streamflow relationships, as well as in development of hydrologic and hydraulic parameters and improved methodologies required for natural resource and environmental quality model testing and simulations. Shirmohammadi et al. (1986) demonstrated that the primary runoff-producing areas within regional watersheds are the low-lying, poorly drained, near-stream areas where the water table is typically near the ground surface throughout the winter and early spring months. Equations commonly used for estimating storm peak flows in current water resource and quality models were tested on storm event data from the LREW and were found to overestimate peak flows by an average of 250% for all events. Improved regional peak flow equations were developed for estimating storm event peak flows occurring on regional watersheds based on watershed physical characteristics (Sheridan, 2002). Improved methods for estimating storm hydrograph characteristics, including the hydrograph time-to-peak parameters (Sheridan, 1994) and hydrograph shape parameters (Sheridan et al., 2002) were developed for hydrologic design and natural resource and environmental modelling applications on ungauged Coastal Plain watersheds. Equations were also developed for estimating mean maximum daily streamflow for a range of recurrence intervals on regional watersheds as a function of watershed drainage area (Sheridan and Mills, 1985).

Documentation of Riparian Ecosystem Services in Agricultural Landscapes. Scientists at SEWRL were the first to document the role of riparian buffers in controlling nonpoint pollution from agricultural watersheds (Lowrance et al., 1984; 1985). Research on the LREW documented the contributions of riparian buffers as long-term nutrient (N, P, Ca, and Mg) and sediment sinks in agricultural watersheds and led to the conclusion that artificial drainage had the potential for adverse water quality effects in the upper Coastal Plain by bypassing riparian buffers. This pioneering work set in motion a line of research that continues to this day and is now being pursued by numerous institutions around the world. The first Riparian Forest Buffer Specification developed by USDA-NRCS and USDA-FS was based directly on this research and the NRCS practice standard for Riparian Forest Buffer (Practice 391) is based on this research. Further studies focused on understanding the effect of management and restoration of riparian ecosystems on water quality and soil functions in a variety of management settings (Lowrance and Sheridan, 2005; Lowrance et al., 2000; Vellidis et al, 2002; 2003). These studies helped guide research efforts on riparian ecosystems that have been conducted by scientists at numerous other institutions including Smithsonian Environmental Research Center, Edgewater, MD; North Carolina State Univ.; Iowa State Univ.; Univ. of Rhode Island; USDA ARS, Beltsville, MD; USDA-ARS, Corvallis, OR; USEPA, Corvallis, OR; and USDA-ARS, University Park, PA in the U.S. and in Denmark, Italy, New Zealand and the United Kingdom.

Developed the Riparian Ecosystem Management Model (REMM). Based on research carried out in LREW, scientists at SEWRL developed REMM and which provides the only management and research tool for simulation of the water quality functions provided by riparian buffer systems of various sizes, soil, vegetation, and adjacent land uses (Inamdar et al., 1999a, 1999b; Lowrance et al, 2000). REMM has been or is being used by researchers at numerous institutions including Cornell, Ohio State, Iowa State, North Carolina State, Florida, Kansas State, USEPA, Athens, GA and USDA-ARS, Florence, SC (examples: Bhat et al, 2007; Graff et al., 2005). REMM was used to assess N removal in forest buffers in Poland, Denmark, and Italy (2001-2008) by the European Union funded NICOLAS project. REMM has been incorporated into the Soil Water Assessment Tool (SWAT) model by cooperators at the University of Guelph, Ontario, Canada. In addition, REMM is being used by agencies such as USEPA and the Delaware Dept. of Environmental Protection to estimate the effectiveness of riparian buffers. Continued development of REMM was recently named a highest priority need by researchers in the USEPA Office of Pesticide Programs Environmental Fate and Effects Division.

Determined Agricultural Effects on Water Quality Impairment. In partnership with Scientists from the University of Georgia, SEWRL scientists used the LREW and similar Coastal Plain watersheds to show that: 1) algal production in streams was generally limited by light availability but that in areas where riparian forests did not shade the stream, excess algal production and oxygen demand may occur due to elevated stream levels of nutrients; 2) sediment oxygen demand (from buried leaf litter and other forest derived organic matter) was higher than estimated on other coastal plain streams; and 3) pathogenic bacteria are more likely to be found in streams draining agricultural watersheds receiving poultry litter than in reference streams (Carey et al., 2007; Todd et al, 2009; Vereen et al, 2007). Findings from these studies have been used by Georgia-EPD to evaluate decisions concerning impaired streams in the coastal plain and numerous agricultural streams have been removed from the impaired list partly as a result of this work.

Validation and Testing of Remote Sensing Platforms. The LREW has played a key role in the validation of aircraft and satellite based sensors. Some of the earliest studies to relate aircraft based measurements to soil moisture conditions on the ground were conducted in 1978 on the LREW (Jackson et al., 1981). Subsequent remote sensing studies were conducted to examine runoff characteristics (Slack and Welch, 1980), evapotranspiration (Szilagyi, 2000), and water quality (Settimi et al., 2010; Wu et al., 2009). More recently, the LREW has been one of the key ARS locations for remote sensing research on soil moisture (Bindlish et al., 2003; Bosch et al., 2006; Bryant et al., 2008; Cashion et al., 2005; Finn et al., 2011; Giraldo et al., 2009a,b; Jackson et al., 2005, 2010, 2011; Thoma et al., 2008). Soil moisture products from satellite sensors have the potential to dramatically improve the accuracy and timeliness of weather, climate, and agricultural assessments and forecasts used by USDA, NOAA, and other agencies. Data collected from the LREW has helped to validate and strengthen research programs utilizing satellite based data from LANDSAT, RADARSAT, ADEOS-II, and AQUA, The LREW was one of the key field locations for the 2003 Soil Moisture Experiments (SMEX). SMEX-GA involved 10 research scientists, 20 graduate students, and a 30-person field crew. The research was the first successful large scale application of remote sensing techniques in the heavily vegetated Coastal Plain. The ARS watershed network has been instrumental in building justification of the launch of the SMAP satellite currently scheduled for 2014. SMAP will provide global measurements of soil moisture and its freeze/thaw state. The SMAP satellite is the first satellite to be dedicated to soil moisture measurements.

Validation and Testing of Watershed Models. The long-term high quality hydrologic and climatic data collected on the LREW have played key roles in advancing the ARS stature as the premier developer of field and watershed scale agricultural models. Scientists at the SEWRL have worked on development and testing or several farm and watershed scale models including AGNPS, Ann-AGNPS, APEX, and SWAT. Rigorous testing and examination of SWAT model simulations have 1) increased confidence in the model, 2) provided valuable insight on hydrologic and water quality conditions in the watershed, and 3) led to critical model improvements. (Bosch et al., 2004, 2010; Chin et al., 2010; Cho et al., 2009; Cho et al., 2010a,b; Feyereisen et al., 2007, 2008; Veith et al., 2010; White et al., 2009; Zhang et al, 2009). Research at the LREW has also led to strong scientific partnerships with several scientists working on model application and testing (Suttles et al., 2003; van Liew et al, 2005, 2007; Wu et al., 2008; Zhang et al., 2011).

Satellite-Derived Maps of Conservation Tillage. A methodology for rapid and unbiased assessments of conservation tillage mapping was developed by the SEWRL that combined a simple land use classification algorithm with two remotely derived indices and could reduce efforts to verify producer compliance with USDA cost-sharing programs by >60%. Results varied from 71 – 78 % accuracy and were best when a minimum of 22 conventional and 22 conservation tillage sites were surveyed. Successful delineation of conservation versus conventional tillage regimes within the LREW was completed as part of the CEAP effort. The tool can provide regular assessments of conservation tillage adoption at the watershed scale and would facilitate federal conservation program implementation, natural resource inventories, and provision of input data for soil and water quality models.

Development and Testing of Mitigation Strategies that Reduce Pesticide Inputs to Ground- and Surface water. Water contamination through off-site movement of pesticides presents significant threats to Coastal Plain ecosystems and drinking water resources. SEWRL scientists have improved understanding of pesticide fate and transport at field, farm, and watershed scales, provided simulation models that effectively quantify these processes, and shown that that low-cost conservation practices may substantially reduce water quality threats. Some of the earliest studies that demonstrated efficacy of grassed waterways in reducing pesticide runoff to streams were conducted at SEWRL (Asumussen et al., 1977; Rohde et al., 1980). Subsequent studies showed that riparian buffers play important roles in attenuating pesticide movement at landscape scales (Lowrance et al., 1997). SEWRL research focused on in-field conservation practices including use of cover-crops, conservation-tillage, and herbicide irrigation incorporation and reformulation can substantially reduce pesticide leaching and runoff while maintaining pest control efficacy (Potter et al., 2004; Potter et al., 2006; Potter et al., 2007; Potter et al., 2008; Potter et al., 2009; White et al., 2009; Potter et al. 2010; Potter et al. 2011). This research has improved the accuracy of pesticide risk assessments used for pesticide registration by contributing data that allow regulatory agencies to quantitatively evaluate conservation practice impact.

Development of Applied Technology for Utilization of Animal Wastes. Scientists at SEWRL: developed and tested overland flow grass-forested vegetated buffer systems for utilizing nutrients contained within animal lagoon wastewater that improved water quality enough to meet standards (Entry et. al., 1999a, 1999b; Hubbard et al., 1998; Hubbard et. al. 1999; Lowrance et al., 2001; Hubbard et al., 2003; Hubbard et al., 2007); demonstrated the environmental efficacy of applying dairy lagoon wastewater to triple cropping systems (Vellidis et al., 1996; Hubbard et al., 2000; Newton et al., 2003); determined poultry litter mineralization rates, appropriate application rates, and long term impacts on soil chemical properties in the Coastal Plain (Gascho et al., 2001; Gascho and Hubbard, 2006; Hubbard et al., 2008); and demonstrated that vegetation can be grown on floating mats in highly contaminated and low oxygen lagooned wastewater from CAFOs and removes N and P from lagoons (Hubbard et al., 2004; Hubbard, 2010; Hubbard et al., 2011).

Development of the CREAMS and GLEAMS Models. ARS-Tifton-SEWRL has been instrumental in the development (Knisel, 1980; Leonard et al., 1987), testing (Leonard et al., 1990), application (Leonard & Knisel, 1988; Truman & Leonard, 1991), and improvement (Bosch, 1991; Truman et al., 1998) of the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) and Groundwater Loadings Effects of Agricultural Management Systems (GLEAMS) models. The CREAMS model was developed to predict nonpoint source pollutant (runoff, sediment, nutrients, pesticides) from field-sized agricultural areas (Knisel, 1980) and evaluated best management practices that would be useful in reducing nonpoint source pollution. The CREAMS model was technology that evaluated the impact of management practices on water quality that subsequently could be transferred to the Soil Conservation Service action agency. In the early 1980s, as a result of groundwater contamination by pesticides, CREAMS was modified to consider the impact of agricultural management practices on pesticide leaching below the root zone. Thus, the GLEAMS model was developed to evaluate complex interactions among soils, pesticide chemistry, climate, and management decisions that affect chemical movement in and through the soil root-zone (Leonard et al., 1987). The GLEAMS model is a field-scale, root-zone model. Both CREAMS and GLEAMS have hydrology, erosion, nutrient, and pesticide components, and operate on a daily time step. Both CREAMS and GLEAMS have numerous users (state and federal governments, private consultants, industry) in multiple countries (40+) around the world, and have had regional, national, and international impact. Both models have created awareness over the years of water quality problems from nonpoint source pollution and aided in understanding of how management practices reduce nonpoint source pollution from agricultural scenarios, especially those practices that action agencies (e.g., NRCS) must evaluate.

INFRASTRUCTURE AND CAPACITY: The Tifton ARS location houses three ARS units that place emphasis on facilities and resource sharing in efforts to enhance both resource use efficiency and opportunities for integration of research efforts:

- The Southeast Watershed Research Laboratory has projects in National Programs 211, Water Availability and Watershed Management; and 212, Climate Change, Soils, and Emissions.
- The Crop Genetics and Breeding Research Unit has research projects in National Programs 205, Rangeland, Pasture and Forages; 307, Bioenergy and Energy Alternatives; and 301, Plant, Microbial and Insect Genetic Resources, Genomics, and Genetic Improvement.
- The Crop Protection and Management Research Unit has research projects in National Programs 303, Plant Diseases; 301, Plant Genetic Resources, Genomics, and Genetic Improvement; and 304, Crop Protection & Quarantine.

ARS research at Tifton encompasses broad subject areas that are critical to agricultural systems in the Southeastern Coastal Plain. Tifton projects are developing improved methods for insect, nematode and weed management using ecologically-based, whole-farm and area-wide approaches that rely on the inherent strengths of our agricultural production systems; breeding stress tolerant and disease resistant crops providing high yield and quality; evaluating scale-dependent effects of agriculture on water quality, irrigation optimization for water demand, effects of tillage on soil moisture and fate of agricultural chemicals. Tifton also houses special research projects include nematode, insect, weed, and pathogen control on IR-4 minor food crops and ornamentals as well as analysis for pesticide residues in IR-4 minor crops.

The Tifton units are core to the USDA Southeastern Regional Biomass Research Center (SERBRC), one of five national centers whose mission is to help accelerate the establishment of commercial biomass production from farms and forests in ways that do not disrupt food, feed, and fiber markets and that enhance natural resources quality. The Director of the SERBRC is housed within the Crop Genetics and Breeding Research Unit at Tifton.

Research planning and implementation among the three units has been increasingly coordinated over the past five years with a common goal of developing profitable agricultural production systems for the Coastal Plain. System goals are to: include biofuels crops, improve environmental quality, reduce agricultural water demand, minimize the importation of animal feeds from outside the region, and incorporate production on marginal lands while maintaining certification for USDA Conservation Program support.

The USDA ARS at Tifton maintains 61,144 ft^2 of office and laboratory space, 29,880 ft^2 of greenhouse/headhouse space, 9512 ft^2 of metal and woodworking shop space, and 48,399 ft^2 of shed and storage space, as well as 122 acres of leased farm land.

The Tifton Location Computer Center/Office of Information Technology supports the Tifton and Dawson locations and is jointly operated by ARS and the UGA Tifton Campus. Both federal and state statistical, computer, and graphics personnel support the Tifton location … including federal and state scientists and support staff. Nineteen buildings and approximately 500 computers are serviced by the Computer Center. About 350 computers are connected to the internet through the Computer Center servers.

DATA AVAILABILITY AND RICHNESS: All data collected on the LREW by the SEWRL are publically available after scientific review. Historical and current data are available on-line via the SEWRL web page (http://www.ars.usda.gov/main/site_main.htm?modecode=66-02-05-00) or archived at the LREW anonymous ftp site (ftp://www.tiftonars.org/) or the STEWARDS database (http://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html). Details on the LREW research program data availability have been published (streamflow - Bosch and Sheridan, 2007; precipitation - Bosch et al., 2007; geography - Sullivan et al., 2007; water quality - Feyereisen et al., 2007; and land management - Sullivan and Batten, 2007).

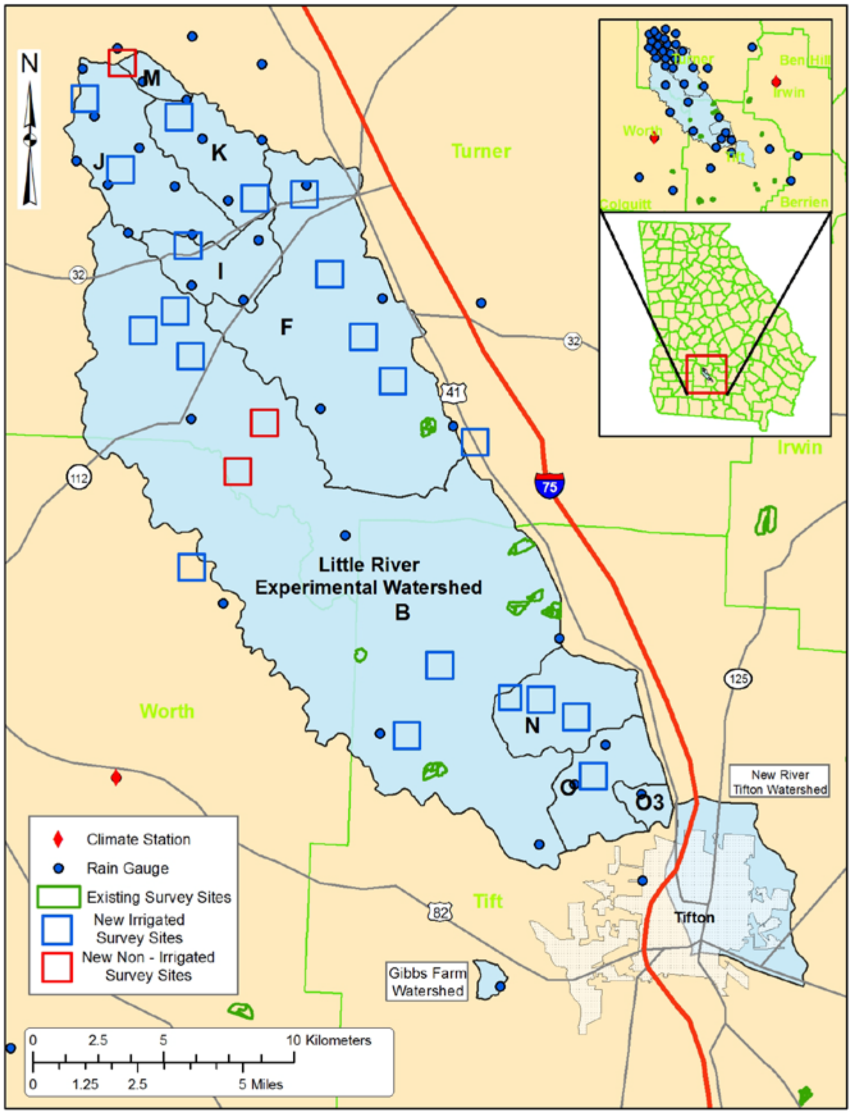

Figure 1. Little River Experimental Watershed, sub-watersheds, and measurement network.

The SEWRL has collected hydrologic and climatic measurements in the LREW since 1968. The LREW is instrumented to measure rainfall and streamflow for the 334 km^2 drainage area and for seven subwatersheds that range from approximately 3 km^2 to 115 km^2 (Fig. 1). The experimental watersheds are located in a paired and nested arrangement that facilitates testing of analytical formulas and modeling concepts. Instrumentation was installed in the late 1960's and early 1970's and has been in continuous operation since that time. Continued operation of this hydrologic network supports hydrologic research as well as environmental quality and riparian research programs of the SEWRL and cooperators. Ongoing data collection from the LREW includes the following networks:

The LREW precipitation and soil moisture network measures rainfall and soil moisture across a 3750 km^2 area (Bosch et al., 2007). The core network was designed to characterize precipitation across the 334 km^2 LREW. Precipitation instrumentation within and immediately surrounding the LREW were installed in the late 1960s and early 1970s (Bosch et al., 2007b). Beginning in 1967, 55 weighing-type digital rain gauge recorders (Brakensiek et al., 1979) were installed in, and immediately surrounding, the LREW. The network was designed to provide a relatively dense spatial measurement on the headwater subwatersheds and more sparse measurement on the remaining basin (Fig. 1). Gauges in the upper watershed were spaced approximately 2.4 km apart, while those in the lower watershed were spaced 4.8 km apart. The justification for this spacing was to provide more accurate rainfall measurement on the smaller headwater areas where variability in rainfall would likely cause greater runoff variability. Beginning in 2003, 13 additional rain gauges were added outside of the LREW in order to monitor a greater portion of the Upper Suwannee River basin, bringing the current number of rain gauges to 46; 31 of which are part of the original network. One minute rainfall data are currently being collected across the entire network.

Stevens-Vitel Hydra probes (Stevens Water Monitoring Systems, Inc.) were added at 29 of the precipitation network sites in 2001 to assess regional soil moisture conditions in the rooting zone (Bosch et al., 2007b). The probes are installed centered at three depths, 50, 200, and 300 mm. The probes measure soil temperature and calculate estimates of soil conductivity and salinity in addition to soil moisture. Measurements are collected every minute and half-hour averages recorded.

The LREW climate network was established in 2004 at three locations in the network (Bosch et al., 2007b). Collected data include: precipitation, soil moisture, total solar radiation, wind speed and direction, air temperature, and relative humidity. The same instruments are used for precipitation and soil moisture as for the other sites. The climate stations were sited to meet data requirements for determining reference crop evapotranspiration (Allen, 1998). They are situated over grass, away from roads, trees, and structures.

The LREW stream discharge network provides fundamental data for research into hydrologic processes, precipitation-runoff relationships, hydrograph characteristics, water yield, and interactive effects of climate, vegetation, soils, and land use for low-gradient Coastal Plain streams. The LREW is currently instrumented to measure streamflow for the 334 km^2 primary drainage area (Watershed B) and seven subwatersheds that range from approximately 3 km^2 to 115 km^2 (Bosch et al., 2007). Construction of the original eight streamflow measurement devices began in 1967 and was completed in 1972. Extensive geologic and hydrologic assessments were conducted prior to installation of the weirs (Yates, 1976). The Virginia V notch weir was selected to fit the design constraints (Ree and Gwinn, 1959). This weir provides accuracy over a wide range of flow rates, including low flow, is less sensitive to submerged flow conditions, and is relatively inexpensive to install and maintain. Because these weirs are normally rated for free-overfall conditions, special laboratory and field studies were conducted to obtain site specific rating curves. The devices were designed so that flows would be contained within the V notch center portion of each weir 90 to 95% of the time. Because of the broad, flat floodplains characteristic of the region, flow measurement installations on the LREW were located at road crossings. Three sites were installed at highway bridges and five at highway box culverts. Each flow measurement site consists of a fixed control (or weir) for constricting and measuring streamflow, steel-sheet piling cutoff walls across the stream channel, guide walls or wing walls to direct streamflow across the control device, a concrete apron for energy dissipation immediately downstream from the control, and stilling wells hydraulically connected to stream sections immediately above and below the control. Weirs at highway bridges were positioned approximately 8 m downstream from the bridges. At all culvert sites except M, weirs were located between the outer ends of the upstream culvert wing walls, approximately 3 m upstream from the culvert. At site M, weirs were placed inside the downslope end of two small box culverts.

The original design flow measurement control section at all sites other than M consisted of a horizontal 0.41 m width weir with a V notch center section. A concrete weir cap was constructed atop an interlocking steel-sheet piling cutoff wall placed perpendicular to the direction of streamflow within the stream channel. Pilings at highway bridge sites were driven into the undisturbed channel bed and the adjacent stream banks for a width equal to the highway drainage opening. Cutoff walls were driven though the loose, unconsolidated, alluvial material into the undisturbed parent material below. The parent material, a relatively impermeable cemented clayey sand, constrains the surface aquifer (Asmussen and Thomas, 1974). Depth of the alluvium, as determined by subsurface borings, ranges from 2 m at the headwater streams to 6 m at the lower end of watershed B (Shirmohammadi et al., 1986). At the bridge crossings, guide walls to prevent bypass flow extend approximately 15 m downstream from the bridge abutments and are high enough to contain the anticipated 25-year flow, with an extra 1 m freeboard added to provide additional capacity for more extreme events (Yates, 1976). Stilling wells are connected hydraulically to the upstream and the downstream sides of the structures. The original instrumentation used to record water surface elevations consisted of two Fischer-Porter digital stage recorders that punched 5-min data in binary decimal code on a 16-channel punched paper tape. Timing on the digital recorders was synchronized across the entire LREW hydrologic network, permitting near simultaneous recording of both upstream and downstream water surface elevations. The original Fischer-Porter recorders measured elevations in increments of 3 mm. Beginning in 1993, the Fischer-Porter gauges were replaced with a strain gauge pressure-transducer digital data logger system to measure and record water surface elevations. The pressure transducers measure the water depth to the nearest 2 mm. The data are stored on data loggers and transferred to computer storage for processing and review prior to entry into the hydrologic database. Five minute streamflow data are currently being collected at all sites.

Data collection and transfer: All precipitation, soil moisture, climatic, and streamflow data are collected and stored by Campbell Scientific data loggers (Campbell Scientific, Inc., 1999). Data are then transferred to the SEWRL base station via land-line, cell phone, or VHF radio transmission at a minimum frequency of one day. Raw data are examined on a weekly basis for possible errors and archived annually. All data collected from the LREW network, dating back to the inception of the network, are available on the SEWRL ftp site (ftp://www.tiftonars.org/).

LREW water quality monitoring data have been collected since the late 1960s (Asmussen et al., 1975; Yates, 1976; Mills et al., 1984). Continuous water quality sampling in the LREW began in 1974 with monitoring of in-stream chloride, nitrate plus nitrite nitrogen, and dissolved molybdate reactive phosphorus concentrations on seven of the eight subwatersheds. In 1979, ammonium, total kjeldahl nitrogen, and total phosphorus were added to the list of analytes monitored. Collection of suspended solids data in the LREW has been intermittent since 1974. Studies were published for records spanning the time frames of: August 1974 to August 1978 on total solids and January 1979 to April 1981 on suspended solids (Sheridan and Hubbard, 1987); and January 1984 to March 1986 on suspended plus dissolved solids (Hubbard et al., 1990). Monitoring of suspended solids concentrations was reinitiated in January 2000 on subwatersheds K, J, I, F, O, and B and in January 2002 on subwatersheds M and N, and continues to present. Details of sample collection and analysis methods have been presented by (Lowrance et al., 1985; Sheridan and Hubbard, 1987; Lowrance and Leonard, 1988; Hubbard et al., 1990; and Feyereisen et al., 2007).

The LREW geographic and conservation practice database contains geographical coverages primarily in vector data format: watershed boundary, county boundaries, tract boundaries, and field boundaries. Also included in this database are the associated 1999 digital orthoquads used to delineate field, tract, and watershed boundaries. Boundary data are available in ESRI ArcView shapefile format and serve as the base layer for all other GIS data. Shapefiles are available designating the current position of: the eight stream sampling stations, 47 tipping bucket precipitation gauges, 29 soil moisture stations, three SEWRL climate stations, five University of Georgia climate stations, and one NRCS SCANS climate station. The database includes topographic, hydrographic, land use, soils, and geologic information collected from various sources. Details of data collection and development procedures can be found in Sullivan et al. (2007). The database also provides records documenting the historical adoption of conservation practices in the watershed through space and time. An associated database file was created containing county names, tract and field numbers, NRCS program under which the practice was granted, NRCS practice number, NRCS practice description, NRCS estimated acreage covered by the practice, the completion date, and whether the practice was of cost or no cost to NRCS. The listed NRCS program acronyms represent the name of the program at the time the conservation practice was completed. Details on conservation practice implementation are presented in Sullivan and Batten (2007).

GEOGRAPHIC COVERAGE: LREW is representative of the Tifton-Vidalia Upland. The Tifton-Vidalia Upland (TVU) is a physiographic subprovince of the Gulf-Atlantic Coastal Plain, which has relatively homogeneous geology, soils, parent materials, land use, agricultural management, and economic and social patterns. The ecologic, economic, and social cohesiveness of the TVU makes it possible to consider the area an ecoregion-"a geographical province with a marked ecological and often cultural unity" (Lowrance and Vellidis, 1995). The TVU is in the northern portion of the Southeast domain as defined by National Ecological Observatory Network (NEON), (http://www.neoninc.org/science/domains). The TVU includes all or most of 28 counties and parts of 16 others in Georgia, an area approximately 52,000 km^2 . The TVU is drained both by rivers that originate in the ecoregion and by major rivers that originate in the Georgia and South Carolina Piedmont and cut through the TVU on their way to the Atlantic Ocean. The climate of the TVU is humid subtropical (Strahler 1975) providing abundant rainfall and a long growing season. Average monthly temperatures at Tifton, Georgia, range from 11°C in January to 27°C in July and August with a mean annual temperature of 19.2°C and mean annual rainfall of 120 cm (Batten 1980).

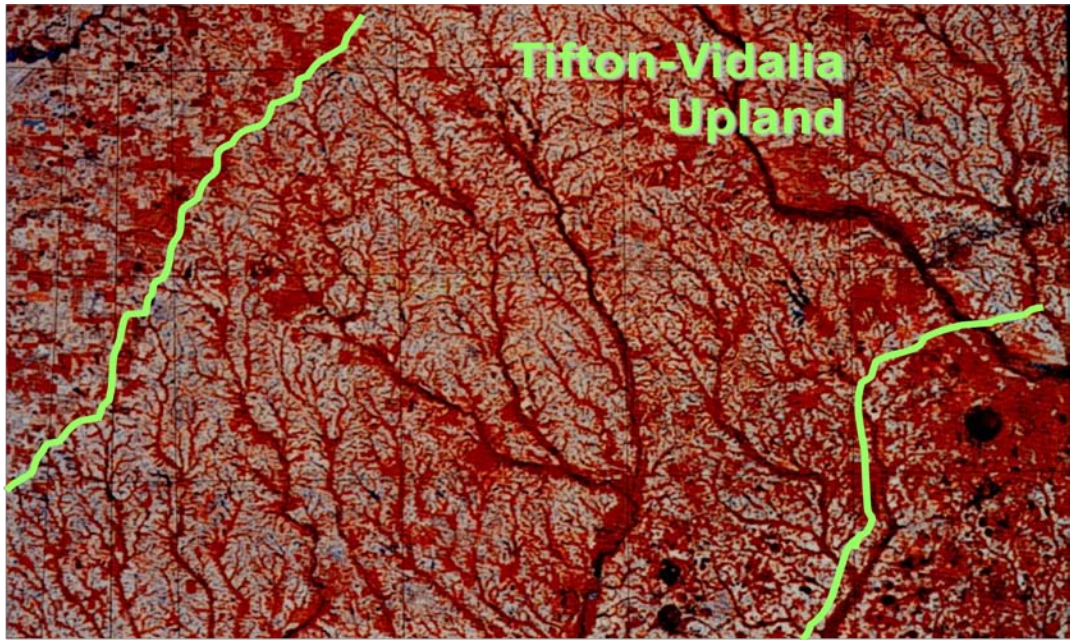

Figure 2. Tifton-Vidalia Upland (false color infrared image).

Topographically, the TVU is an area of floodplains, river terraces, and gently sloping uplands. Bottomlands are nearly level and most valley flanks are less than 5% slope although some slopes of 5%-15% exist. The TVU is underlain by the upper part of the Hawthorne Formation, which is composed of Miocene age sediments (Asmussen and Ritchie 1969). The Hawthorne Formation forms an effective aquiclude since it transmits water at a much lower rate than the porous medium above it. The aquiclude causes most infiltrated precipitation to halt its downward movement and move laterally to the stream channels. The generalized hydrology and landscape of the TVU is illustrated in Figure 2, taken from a false color infrared image of Georgia. The dense dendritic network of stream channels is bordered by riparian forest wetlands (dark areas) with the upland areas devoted to mostly agricultural uses (bare ground in white). Surface waters are primarily used for irrigation, fisheries, and recreation. Shallow groundwater contributes to streamflow and farm ponds but deeper groundwater from the Floridan Aquifer is used for municipal and rural domestic water supply, irrigation, and industries in this portion of the coastal plain. Because infiltrated rainfall cannot move effectively beneath the Hawthorne formation, recharge to the Floridan Aquifer below the Hawthorne is minimal within the TVU and the Floridan is mapped as confined or semi-confined throughout the TVU region. Soils of the TVU are formed primarily from the Hawthorne Formation with minor areas formed from eolian sands. Most of the upland soils are classified as fine-loamy (or loamy), siliceous, thermic Plinthic Kandiudults. The bottomland soils are primarily loamy, siliceous, thermic Arenic Plinthic Paleaquults with some Fluvaquents and Psammaquents (Calhoun 1983). Most of the upland soils contain plinthite, a "sesquioxide-rich, humus-poor, highly weathered mixture of clay with quartz and other diluents" (Calhoun 1983), which forms an aquitard and can cause perched water tables.

Vegetation of the TVU has changed drastically from presettlement times due to logging, agriculture, and silviculture. The entire region was once called "Wire Grass country" because of the longleaf pine/perennial wiregrass community (Harper 1906). Little of the original upland vegetation exists within the TVU. Most upland areas have been converted to either agricultural uses or pine plantations. Many poorly drained areas of the ecoregion are still occupied by vegetation similar to the original pre-settlement plant communities. The wetland ecosystems within the TVU have been described by Wharton (1978) as blackwater (nonalluvial) river systems. According to Wharton's description, this includes both the blackwater river and swamp system and the tributary streams described as blackwater branch or creek swamps. The Withlacoochee, Little, and Alapaha rivers inundate their fairly narrow floodplains for long periods of time. Swamp black gum (*Nyssa sylvatica* var. biflora (Walt) Sarg.) dominates the floodplains where water movement is restricted. Water tupelo (*Nyssa aquatica* L.) and bald cypress (*Taxodiurn distichum* (L.) Rich.) tend to grow in more open water with more circulation. The riparian areas along these streams are sometimes dominated by low areas of slash pine (Wharton 1978). These broadleaf tree and shrub communities occur as bands of vegetation on moist organic soils along small streams. In the modern-day TVU, these riparian ecosystems are often juxtaposed with agricultural lands and form effective buffer systems trapping sediment and nutrients from moving to streams.

Present land uses in the TVU are dominated by agriculture and forestry. The land in farms accounts for about 35 % of the total area of the TVU countries (Georgia Statistics System, 2011, http://www.georgiastats.uga.edu/guide.html). Total row crop land in the TVU counties is about 18% of the land area. The remaining land in farms is primarily in woodland or pastureland. The 65% of the TVU counties that is not in farms is primarily privately owned forest land with about 5% of the TVU counties in urban, suburban, rural housing, or transportation uses. The population of the TVU grew by about 10% in 200-2010. The growth was uneven, although most counties increased in population. In 2010, 42% of the population was urban. The rural nonfarm population was the majority (51 %) of the population. Despite the importance of agriculture to the region, the farm population was only 7% of the total (Georgia Statistics System, 2011, http://www.georgiastats.uga.edu/guide.html).

PARTNERSHIPS: Scientists with the SEWRL have a strong history of partnership with ARS scientists, other federal and state agencies, universities, and private interests. From the inception of the watershed, the ARS has closely partnered with the University of Georgia to complement its research expertise. This partnership has been extremely productive and was responsible for many of the advances in understanding of riparian ecosystems and regional water quality. The SEWRL has historically worked closely with scientists of the USGS to compliment the research strengths within the unit. The partnership with the USGS has allowed the SEWRL to maximize its research efforts, working with the USGS to utilize their hydrologic expertise throughout the region. Partnerships with the USDA NRCS have allowed the SEWRL to closely study management practices throughout the LREW and their impact upon water quality. SEWRL scientists have historically worked closely with ARS scientists from other locations to compliment its research program and maximize our resources. As demonstrated through our productivity, the LREW research has allowed the SEWRL to build strong and productive partnerships with scientists from many Universities and Institutes. Below is a partial list of scientists the SEWRL has historically partnered with:

- ARS: Michael Cosh, Thomas Jackson, Gary Heathman, Mary Susan Moran, John Prueger, Patrick Starks, Martha Anderson, S. Bhat, Rajat Bindlish; Mark Seyfried, Jeff Arnold, Mark Walbridge, Roger Kuhnle, Jean Steiner, Mark Tomer, Tamie Veith; Gary Feyereisen; William Anderson; Corley Holbrook; Brian Scully; Ted Webster; Marshall Lamb.
- USGS: Michael Finn, E. Lynn Usery, Kristina Yamamoto
- University of Georgia: Craig Kvien, Gary Hawkins, George Vellidis, Andrew Mehring, Cathy Pringle, Marguerite Madden, Jason Todd, John Beasley, Sharad Phatak, Larry Newton, John Barnard, Dewey Lee,
- Other Universities and Research Institutes: Mario Giraldo (Kennesaw State); Jimmy Williams (Texas A&M); Minha Choi and Jennifer Jacobs (New Hampshire); Ali Saleh (Tarleton); J.F. Joseph (Texas);); Raghavan Srinivasan (Texas A&M); David Chin (Miami); Donna Sakura-Lemessy (Albany State); Mike VanLiew (Nebraska); Peter Allen (Baylor); Victoria Keener (Florida); Adel Shirmohammadi and Hubert Montas (Maryland); Christopher Wilson (Iowa); Amir Nejadhashemi (Michigan State); Shuo-sheng Wu (Missouri State); Eric White (Cornell); Valerie Thomas (GATech), John Settimi (Abraham Baldwin Agricultural College);
- International: Jaepil Cho (Rural Research Inst., Korea); Martin Volk (Helmholtz Centre for Env. Research, German); Jinyang Du (Inst. of Remote Sensing Applications, China); Per Ambus (Denmark); Maurizio Borin, Bruna Gumiero (Italy).
- Private Industry: Dana Sullivan (TurfScout Inc.); Eric Schilling (National Council for Air and Stream Improvement, Inc.); David Lewis and Russell Kincaid (Institute for Technology Development); Xuesong Zhang (Joint Global Change Research Institute, Maryland)

From the inception of the LREW network, scientists with the SEWRL have worked closely with private land-owners across the watershed. Formal agreements have been drafted with each landowner for each of the rain gauges installed within the network. This strong collaboration has led to many research studies across the watershed. Farmers across the LREW have been extremely cooperative in allowing access to their fields for scientific research and formal land use agreements are in place with 25 producers in the region. This strong partnership has facilitated many field campaigns that have collected watershed scale assessments.

***Integrative mission of Southeast Watershed Research Laboratory*:** The lab's mission is to develop the scientific understanding and associated technologies of watershed systems essential to maintain and enhance the environmental and natural resource base upon which a viable, sustainable, and productive agricultural economy depends. The laboratory's focus is primarily on the Atlantic Coastal Plain region of the southeastern U.S., a region with low-gradient drainage systems and extensive near stream riparian areas. SEWRL seeks to provide:

- An understanding of physical, chemical, and biological processes that interact within agricultural and natural resource systems;
- Methods to improve the use of soil and water resources in the production of quality food, fiber, and fuel while maintaining short- and long-term productivity requirements, ecosystem stability, and environmental quality;

- Practices to control soil erosion, sustain soil productivity, and prevent adverse downstream impacts from sedimentation in streams, ponds, buffers and wetlands within agricultural landscapes;
- Region-specific measures of the fate and transport of carbon, nitrogen, phosphorus, pesticides and other environmentally significant water and sediment transported substances that are used in or have their mass and distribution affected by agriculture; and
- Models, information systems, and field validation data to guide responsible management decisions for action and regulatory agencies at field, farm, and watershed scales to facilitate research and transfer of technology to customers.

Provision of this information is most effectively accomplished in partnership with other ARS units and locations, universities, non-governmental organizations (NGOs) and private producers. The Tifton ARS location houses three ARS units that place emphasis on facilities and resource sharing in efforts to enhance both resource use efficiency and opportunities for integration of research efforts:

- The Southeast Watershed Research Laboratory has projects in National Programs 211, Water Availability and Watershed Management; and 212, Climate Change, Soils, and Emissions.
- The Crop Genetics and Breeding Research Unit has research projects in National Programs 205, Rangeland, Pasture and Forages; 307, Bioenergy and Energy Alternatives; and 301, Plant, Microbial and Insect Genetic Resources, Genomics, and Genetic Improvement.
- The Crop Protection and Management Research Unit has research projects in National Programs 303, Plant Diseases; 301, Plant Genetic Resources, Genomics, and Genetic Improvement; and 304, Crop Protection & Quarantine.

ARS research at Tifton encompasses broad subject areas that are critical to agricultural systems in the Southeastern Coastal Plain. Tifton projects are developing improved methods for insect, nematode and weed management using ecologically-based, whole-farm and area-wide approaches that rely on the inherent strengths of our agricultural production systems; breeding stress tolerant and disease resistant crops providing high yield and quality; evaluating scale-dependent effects of agriculture on water quality, irrigation optimization for water demand, effects of tillage on soil moisture and fate of agricultural chemicals. Tifton also houses special research projects include nematode, insect, weed, and pathogen control on IR-4 minor food crops and ornamentals as well as analysis for pesticide residues in IR-4 minor crops.

The Tifton units are core to the USDA Southeastern Regional Biomass Research Center (SERBRC), one of five national centers whose mission is to help accelerate the establishment of commercial biomass production from farms and forests in ways that do not disrupt food, feed, and fiber markets and that enhance natural resources quality. The Director of the SERBRC is housed within the Crop Genetics and Breeding Research Unit at Tifton.

Research planning and implementation among the three units has been increasingly coordinated over the past five years with a common goal of developing profitable agricultural production systems for the Coastal Plain. System goals are to: include biofuels crops, improve environmental quality, reduce agricultural water demand, minimize the importation of animal feeds from outside the region, and incorporate production on marginal lands while maintaining certification for USDA Conservation Program support. SEWRL has established several collaborations as part of its overall mission to improve our understanding of the effects that interactions between environmental change and human use of natural resources have on the provisioning of ecosystem services (e.g., food, fiber, and fuel production, adequate clean water, trace gas emissions reductions and carbon sequestration) from agricultural landscapes. These collaborations are designed to (Fig. 3):

1) Improve understanding of the relationships between soil and perennial grass production, including soil carbon and nitrogen dynamics, plant available soil-water, soil microbial biomass, greenhouse gas fluxes, and nitrogen use efficiency (in partnership with Anderson and Lamb CRISs).
2) Improve understanding of the potential for winter cover legumes to increase soil carbon and nitrogen accretion, crop yield and biomass production, and crop nitrogen use efficiency in a sorghum-cotton rotation (in partnership with Scully CRIS).
3) Determine the impact of gypsum application (magnitude, time lag, and post treatment hysteresis) in a Tifton sandy loam managed under a sweet sorghum-peanut-cotton conservation tillage system on:
    a. Rooting depth, soil bulk density, water infiltration rate, sediment yields and characteristics, soil-water distribution, and soil-water balance.
    b. Pesticide soil persistence (including metabolite accumulation and decay) as influenced by soil properties, pesticide formulation, and pesticide application practices.
    c. Estimated surface and sub-surface water loss rates and associated edge-of-field loads for sediment, carbon, nitrogen, and pesticides (includes degradates).
    d. Fluxes of CO_2, CH_4 and N_2O during sorghum years.

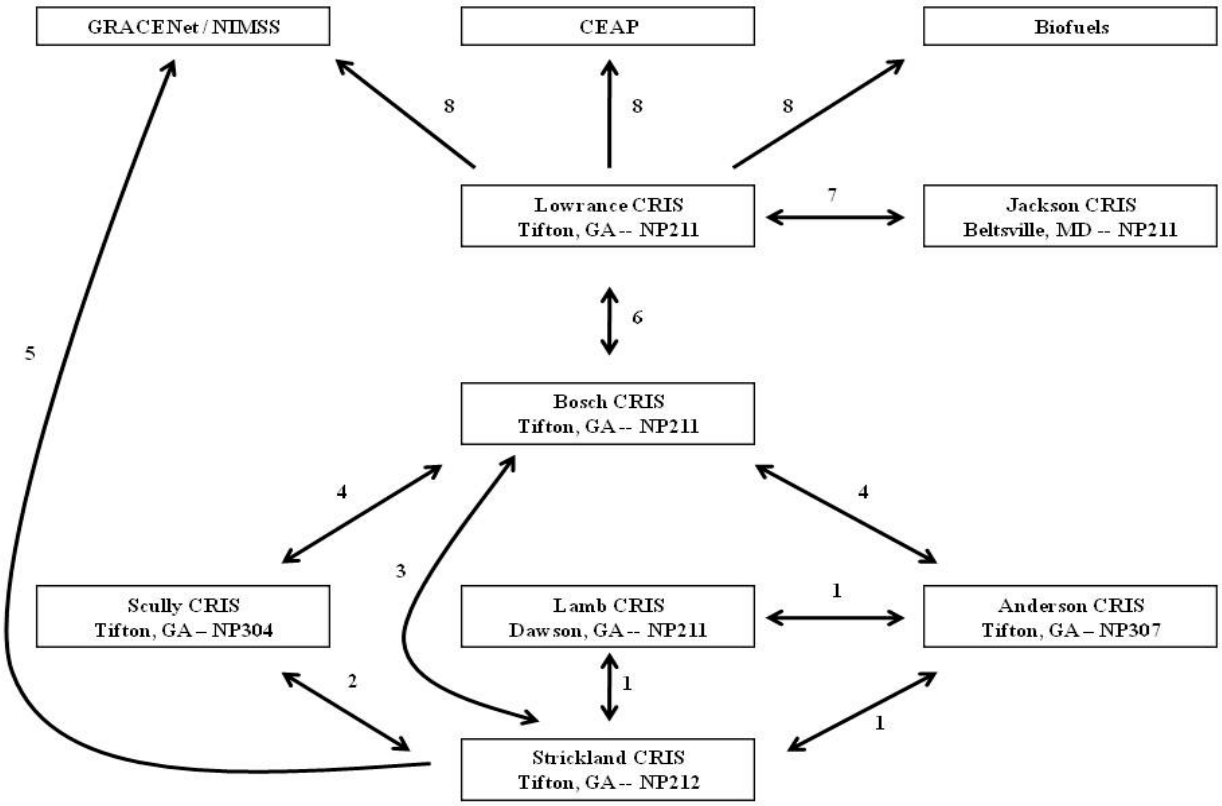

Figure 3. SEWRL research program collaborations.

The products of this project are specifically designed to serve SEWRL, ARS, and partner needs by (also Fig. 3):

4) Providing process information that will improve parameterization of input data (C&N accretion and cycling rates, water availability and quality effects, evapotranspiration estimates, yield potential and yield indices) for crop production and watershed model calibration and for producers' decision making (Bosch CRIS).

5) Delivering site-specific C&N cycling and trace gas data to the ARS Greenhouse Gas Reduction through Agricultural Carbon Enhancement (GRACENet) database and to the Southern Multistate Research Committee's project S1048, "Assessment of the Carbon Sequestration Potential of Common Agricultural Systems on Benchmark Soils across the Southern Region Climate Gradient." S1048 data will be archived in the Land Grant Universities' National Information Management Support System (NIMSS).
6) Delivering soil quality and hydraulic data that will aid in the development of:
   a. Conservation practice targeting recommendations and mitigation effects forecasts for most sensitive landscape positions within farms (Bosch CRIS).
   b. Hillslope-small watershed soil conductivity models and parameterizations for Little River Experimental Watershed (LREW) (Lowrance CRIS).
   c. Modify REMM to include upland-to-riparian transitional zone and to predict potential perennial grass biomass yields from buffers (Lowrance CRIS).
7) Providing improved understanding of the relationships between crop water use efficiency, soil characteristics (texture, bulk density, carbon content, soil-water holding capacities), and crop biomass production that will facilitate validation of soil water estimation by satellite (Jackson CRIS).
8) Providing improved information on the effects of conservation practice, future land use, and environmental change scenarios for the southeastern coastal plain region to integrated National Program Assessments' "what-if" analyses (Conservation Effects Assessment Project, CEAP; the USDA ARS Southeastern Regional Biomass Research Center, Biofuels; and GRACEnet).

Collaborating Multiple Location Projects: The LREW is a key site in several Multi-Location research Projects (MLPs) which use observations and analyses from long-term ARS and USDA experimental watersheds, ranges, and forests. These MLPs systematically test common hypotheses at locations across the continental United States, using long-term, high-resolution observations in time and space. A listing of the objectives and hypotheses of MLPs that include the LREW follows. Identification numbers are provided that relate back to outputs and products listed in the ARS Water Availability and Watershed Management Action Plan for 2011-2015: (http://www.ars.usda.gov/research/programs/programs.htm?np_code=211&docid=17585).

1. *MLP 4.1.2 Utility of Remote Sensing for ET and Drought Monitoring and for Assimilation into ARS Hydrologic Models; Led By Dr. Wade Crow (USDA-ARS, Beltsville, MD)* - The MLP will use long-term measurements acquired at USDA-ARS watersheds to provide an objective analysis of available remotely sensed data for detecting the onset and severity of agricultural drought. These techniques could add significant utility to current operational drought monitoring activities based on precipitation observations and unconstrained water balance modelling. In particular, the development of new land data assimilation techniques suggests that existing models can be dynamically updated using remotely-sensed soil moisture estimates and improve the accuracy of the hydrologic model (with regard to drought detection) by correcting for the degrading impact of model forcing and parameterization errors. Systematic comparisons between ground observations of drought-related variables, existing hydrologic models, and remote sensing retrievals will be employed to clarify the value - and/or limitations - of remote sensing retrievals for drought applications over a range of land cover types. *Participants:* Wade Crow, Martha Anderson, William Kustas, Joseph Alfieri, Pat Starks, Daniel Moriasi, **David Bosch**, David Goodrich, Susan Moran, Jack Morgan, Rebecca Philips.

2. *MLP 4.2.4. Remotely-derived estimates of Net Primary Production using remotely sensed data across Precipitation Regimes; Led By Dr. Susan Moran (USDA-ARS, Tucson, AZ)* - The MLP will produce continental-scale synthesis of high-resolution observations from ARS and USDA experimental watersheds, ranges, and forests, to quantify the impacts of climate variability and change on agro-ecosystems. The hypothesis is that ecosystem processes converge to a common feedback pattern that is

not apparent in short-term studies or by site-level models alone. The general goal is to discover "convergence" of ecohydrologic patterns within Multi-Location, Time-Series, Eco-Hydrologic (MLTSEH) data that could allow generalization to other locations using the historic multi-disciplinary >30-year data record of 81 USDA experimental sites; the 10-year MODIS Enhanced Vegetation Index (EVI) time series; and will address the hydro-ecological *feedbacks* related to climate change (e.g., temporal/spatial precipitation patterns, frequency of extreme events). *Participants:* D. Goodrich, M. Nearing, Mitch McClaran (Univ. Arizona), Mark Seyfried, Danny Marks, John Sadler, Deb Peters, Jack Morgan, **David Bosch, Tim Strickland,** Patrick Starks, Stacey Gunter, Ray Bryant, Alfredo Huete (University of Technology Sydney, Australia), Mary Beth Adams (USDA-FS)

3. *MLP 4.3.4. Hydro-Climatic Trends characterized across North America.—A comparative analysis of historical soil water trends in US agricultural lands; Led by Dr. Mark Seyfried ARS (Boise, ID)* - The MLP will organize soil climate (water content and temperature) data from ARS sites to describe and compare soil climatology across sites in terms of atmospheric climate and temporal trends possibly related to climate change and landscape features and management. The hypothesis is that a comparative analysis of soil climate across the US will improve our understanding of differences in soil processes and in the impact of climate change that are not expressed in atmospheric climate measurements. Variations in soil processes across space and time may be quite different from what we might expect from the atmospheric climate. For this reason, we might expect that actual changes in soil climate may differ substantially from what climate models are currently indicating, and expected changes between locations may be quite different from changes predicted from the climate. For example, soil water has been monitored since the late 1970's and soil temperature monitored since 1990 (Seyfried *et al.*, 2001a) at the Reynolds Creek Experimental Watershed in Idaho. At that site even longer-term climate data have shown a nearly 2° C temperature rise with no trend in precipitation amount. Questions to address include: What are the differences among sites? Are trends significantly different among sites relative to the atmospheric climate? Are there general statements we can make regarding observed trends? *Participants*: M. Seyfried, T. Keefer, P. Starks, **D. Bosch**, S. Evett, P. Kleinman, S. Dabney, T. Green, J. Sadler, D. Peters, J. Bonta.

4. *MLP 4.6.4 Estimate the impacts of projected climate change on regional water availability and quality (including watershed sediment yield), across diverse physiographic regions of the United States, and their associated implications for conservation needs and agricultural productivity; Led by Dr. Jurgen Garbrecht ARS (El Reno, OK).* The MLP will quantify the magnitude of climate warming and concurrent changes in humidity, precipitation and streamflow across agricultural regions of North America over the past 4 – 5 decades and hypothesizes that trends and change in climate will impact basin response components in significantly different (>10%) magnitude and direction across different North American experimental watersheds. This project will involve a comprehensive hydro-climatic assessment of the ARS watersheds, treating them as a network that can be used to assess the geographic distribution of climate warming and associated changes in humidity, precipitation and streamflow. This effort is an initial step in assessing the sensitivity of watershed-based agricultural systems to changes in hydro-climatic conditions. In the process of evaluation of trends in temperature, precipitation and streamflow, methodologies will be developed for determination of precipitation phase, definition of topographic and spatial distributions and identification of event timing and magnitude. The project will compare historical downscaled and pre-defined precipitation patterns (PRISM) to those determined from high-resolution patterns measured within the ARS watersheds. *Participants:* D. Marks, D. Goodrich, J. Garbrecht, **D. Bosch**, P. Kleinman, S. Dabney, J. Sadler, D. Harmel, K. King, J. Pomeroy (Marmot Creek, Alberta), Claire Baffaut, Ron Bingner, Daniel Moriasi, **Tim Strickland**, John Zhang, Anthony Buda, Jim Bonta.

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