APPLICATION TO THE USDA-ARS

LONG-TERM AGRO-ECOSYSTEM RESEARCH (LTAR) NETWORK

FOR THE

SOUTHWEST WATERSHED RESEARCH CENTER'S

WALNUT GULCH EXPERIMENTAL WATERSHED

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1. INTRODUCTION AND PRODUCTIVITY

From its initial inception in 1951 as the "Southwest Watershed Studies Group" under the Office of Research and Development of the USDA-Soil Conservation Service, the USDA-ARS Southwest Watershed Research Center (SWRC) has developed and maintained a world-class research program with extensive outdoor laboratories consisting of experimental watersheds and ranges. Over 2150 publications have been produced by the SWRC (http://www.tucson.ars.ag.gov - see "Publications Link"). Among the many honors achieved by current and past SWRC scientists there have been three supergrade scientists, two ARS Area Scientists of the Year, a member of the National Academy of Engineering and numerous national awards. A particular strength of the unit has been national leadership in the development of hydrologic and erosion simulation models, including the lead or co-lead of RUSLE, EPIC, WEPP, Kineros, RHEM and the AGWA model interface. The SWRC currently has eight permanent research scientists and maintains research facilities in Tucson and Tombstone, Arizona. The primary laboratories of the SWRC are the Walnut Gulch Experimental Watershed (WGEW) and 8 small experimental watersheds on the University of Arizona Santa Rita Experimental Range (SRER) (http://ag.arizona.edu/srer/)[1]. This application to the Long-Term Agro-Ecosystem Research (LTAR) network focuses on the WGEW.

The WGEW is one of two ARS experimental watersheds on western rangelands and is the only one in the semiarid Southwest. It is one of the most intensively instrumented semiarid experimental watersheds the world, with a 10- to 100-year record of abiotic and biotic measurements and photographs. The 150-km^2 watershed is located in the transition zone between the Sonoran and Chihuahuan deserts (31°430N, 110°410W) in southeast Arizona. The WGEW elevation ranges from 1220 to 1950 m, with desert shrubs dominating the lower two thirds of the watershed and desert grasses dominating the upper third. The climate at WGEW is classified as semiarid, with mean annual temperature of 17.7°C and mean annual precipitation of 312 mm. The land comprising WGEW is under the ownership and control of other federal agencies, the state of Arizona, private landowners and leaseholders. The SWRC has made a concerted effort to make observations, knowledge, and data from its outdoor laboratories readily available via the internet (www.tucson.ars.ag.gov/dap - see sections 3-4 and Moran et al., 2008).

The stature of the WGEW has also been elevated through highly successful trans-disciplinary research campaigns, such as Monsoon '90 (Kustas and Goodrich, 1994), the Semi-Arid Land-Surface-Atmosphere (SALSA) Program (Goodrich et al., 2000) and the Soil Moisture Experiments in 2004 (SMEX04) (Jackson et al., 2008). Research from the WGEW, these trans-disciplinary experiments, and their extension into the larger San Pedro River Basin (SPRB) has resulted in direct consultation with decision makers and elected officials of the Upper San Pedro Partnership (http://www.usppartnership.com/) and major contributions to larger trans-disciplinary research programs and monitoring networks. These include the selection of the WGEW/SPRB as: 1) One of the first five basins in the world to be considered an operational UNESCO Hydrology for the Environment, Life, and Policy (HELP) basin; 2) a key research site for the first water centric NSF Science and Technology Center for the Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA); and 3) The AGAVES (Assessment of Goods and Valuation of Ecosystem Services) research program (http://rmgsc.cr.usgs.gov/agaves/). Researchers from many universities and agencies around the world conduct research within the WGEW, building on the exceptional knowledge base and research infrastructure provided by this unique agro-ecosystem laboratory to further the mission of USDA, ARS, and the SWRC to develop knowledge and technology to conserve water, soil, and improve the science used for rangeland management in semiarid lands.

[1] The SRER is the core site for the Southwest National Ecological Observatory Network (NEON) domain and has a long-term history dating back to 1903.

2. INFRASTRUCTURE CAPACITY

The SWRC has operated the WGEW (Fig. 1) since the mid-1950s as an outdoor laboratory for research on erosion and hydrologic processes. WGEW is contained within the 7600 km^2 upper San Pedro River Basin in Sonora, Mexico and Arizona. Cattle grazing is the primary land use with mining, limited urbanization, and recreation making up the remaining uses. The main channel of the watershed, Walnut Gulch, is an ephemeral tributary of the San Pedro River.

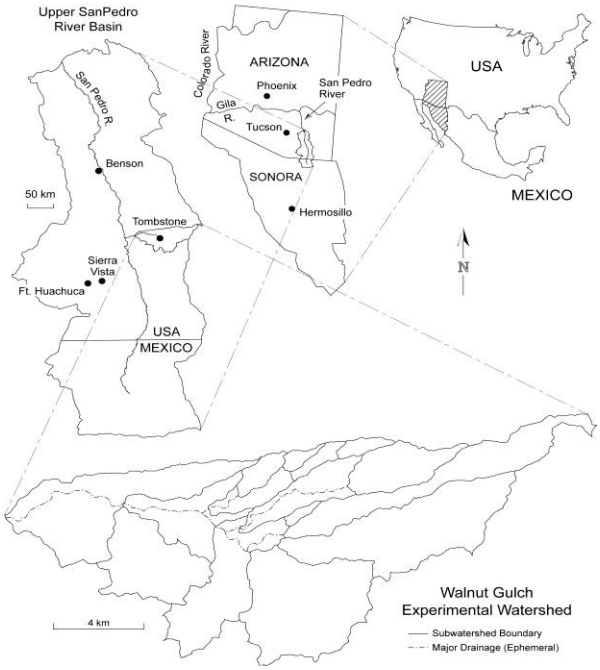

Figure 1. Location of WGEW

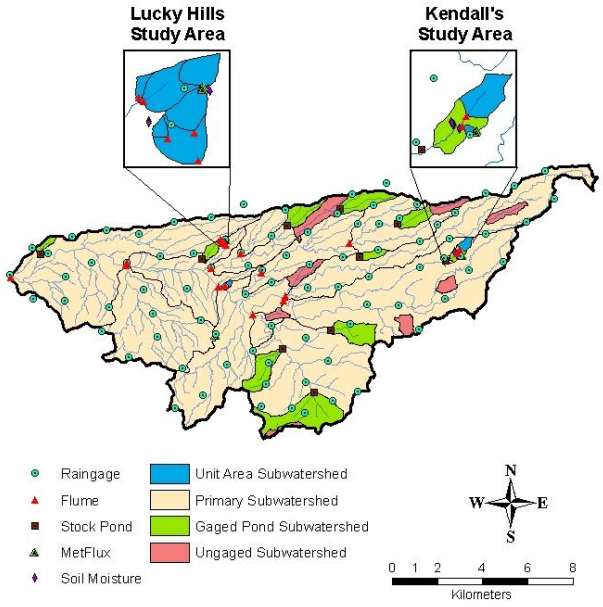

Figure 2. Instrumentation at WGEW

Hydro-meteorological and soil erosion/sedimentation data are collected from 125 instrumented installations on the WGEW (Fig. 2). Precipitation is measured with a network of 88 weighing-type recording rain gauges arranged roughly in a grid throughout the watershed to capture both interstorm temporal dynamics at the point scale and the spatial variability typical of thunderstorm rainfall at the landscape scale. Surface runoff is measured at a range of scales to isolate the effects on runoff of interactions of rainfall intensity with soil and vegetation characteristics at small scales and channel network processes and rainfall spatial variability at larger scales. In addition, the nesting of watersheds at a range of scales allows for internal verification and validation of distributed simulation models. Runoff is measured at 9 small (termed "unit area" in Figure 2) watersheds (.2 to 6 ha) by structures including a broad-crested V-notch weir, two H-flumes, and six Santa Rita supercritical flow flumes. Runoff from watersheds greater than 35 ha is measured using either livestock watering ponds or large supercritical flow flumes. The largest flume, at the outlet of the WGEW, has a flow capacity of 650 cubic meters per second. Currently, 7 stock pond watersheds and 11 large flume watersheds are instrumented. Sediment from the small watersheds is sampled either with automatic pump samplers or with total-load automatic traversing slot samplers. Sediment accumulation in the stock ponds is measured through periodic topographic surveys of the ground surface of each stock pond. Meteorological, soil moisture and temperature, and energy/water/carbon dioxide flux (eddy covariance) measurements are made at two vegetation/soil complexes. These two intensive study areas, the brush

covered Lucky Hills and grass dominated Kendall, are similarly instrumented and each is representative of one of the two dominant vegetation communities on WGEW. Near-surface soil moisture/temperature sensors are co-located with 19 of the network rain gauges. Eighty-three permanent vegetation transects are monitored to evaluate the impacts of management practices and climate change on vegetation dynamics.

In addition to WGEW, the SWRC measures precipitation, runoff, and sediment on eight small watersheds (since 1974) and has two metflux sites (since 2004) at the University of Arizona's Santa Rita Experimental Range (SRER) south of Tucson. The SWRC also maintains a network of precipitation gauges and meteorological and flux stations throughout the Upper San Pedro River Basin (USPB) in western Cochise County, AZ. SWRC instrumentation at SRER and USPB includes 34 recording raingauges, 8 runoff measuring stations, 8 sediment monitoring stations, one automated weather station, 32 near-surface soil moisture sites and three CO2/H2O flux stations.

All WGEW, SRER and USPB stations are equipped with dataloggers and radio telemetry for automated data sampling and collection. All stations are queried by base stations every 24 hours, data are collected and archived in redundant locations, and stored for processing on servers at the SWRC offices in Tucson. Preliminary daily summaries are available by 6:00am for the nominal 24 hour period 0001 to 2400 of the previous day. Fully quality-controlled data, including precipitation and runoff rates, sub-hourly continuous meteorological and soil moisture, and daily, monthly or annual aggregated are available within a few weeks. Quality checked and controlled data from the flux stations are archived and available at the Ameriflux website.

The SWRC Tucson location consists of 6 buildings including office space and three laboratories: a chemical analysis laboratory, a soils analysis laboratory, and a GIS laboratory. The computer facilities at Tucson consist of Windows servers configured to run in a Windows Domain environment. They include two domain controllers, five NAS file servers, two database servers, and two application servers. Incoming data from the field are stored on the NAS servers where read access is shared to the local network. All critical data is backed up by an LTO-4 tape backup unit, currently at about one terabyte in capacity, where the tapes are stored offsite. A Cisco firewall is used to partition public application servers from the rest of the internal network. Additional computer facilities include approximately 50 PC's also configured to run in the Windows Domain. Duplicate network equipment is available to facilitate near-immediate recovery in the event of hardware failure.

Hydrologic data are currently stored in a proprietary database schema, processed using in-house programming and scientifically-accepted methods, and distributed via custom web applications in public-friendly formats such as Microsoft Excel spreadsheet. These data are available for public use (http://www.tucson.ars.ag.gov/dap/) under condition of professional courtesy that SWRC is cited in scientific publications. Plans are underway to adapt these data to the WaterML format under development by the Consortium of Universities for the Advancement of Hydrologic Science, Inc. Flux data at the Ameriflux server are available to all researchers under an Ameriflux fair-use policy.

The field station at Tombstone consists of three buildings. Additional field equipment, in addition to those listed above, include rainfall simulators, a mobile time-domain reflectometry unit, LAI meters, hand-held radiometers, and surveying equipment including a Differential Geographic Positioning System (DGPS). Two dedicated Windows desktop computers running communication software are base stations for the radio transmission to the remote measurement sites. The field station at Tombstone includes offices, soils laboratory, electronics, machine and mechanics shops, and a residential trailer for

temporary overnight stays to accommodate Tucson staff and visiting scientists and students. The Tombstone field offices also have a Windows based network of 10 computers with a Cisco firewall and connection to the Tucson SWRC offices. Field support equipment includes a backhoe, a 3500 gallon water truck, two dedicated 4WD service trucks, several additional 4WD vehicles, and portable electric and gas welders.

3. DATA RICHNESS

There is inherent value in the sheer length of data collection at WGEW, but even more value is obtained through the broad spectrum of disciplines (Table 1). This includes decadal records of watershed-scale vegetation dynamics, temporally continuous and spatially extensive meteorological and rainfall/runoff measurements, automated collections of storm sediment yield, and one of the few long-term records of soil moisture at multiple depths and locations. In addition to the long-term, high-quality ecohydrologic data collection, hundreds of satellite and aircraft spectral images of WGEW have been acquired and extensive geographic information system (GIS) databases are available.

Table 1. WGEW long-term measurements of hydrology, climate and vegetation. Most data are available at SWRC web site (http://www.tucson.ars.ag.gov/dap/) and in a standardized format through the EcoTrends Project, the Arizona Regional Image Archive and other networks (Table 2).

Data	Instrumentation	Record	Reference
Rainfall	Current network of 88 gages	1953 to present	Goodrich et al. 2008
Runoff	30 instrumented watersheds	26 to 47 years, and continuing	Stone et al. 2008
Sediment	9 instrumented watersheds and 10 stock tanks	Early 1960s to present	Nichols et al. 2008
Standard Meteorological Measurements	Automated weather stations at Lucky Hills and Kendall watersheds, and Tombstone headquarters	1990 to present	Keefer et al. 2008
Soil Moisture and Temperature (multiple depths)	Sensors at Lucky Hills and Kendall watersheds Sensors at 19 locations in WGEW	1996 to present 2003 to present	Keefer et al. 2008
Vegetation	Permanent transects at 13 to 55 sites	1967, 1994, 1999, 2005, and continuing	Skirvin et al. 2008
CO_2 & H_2O flux	Bowen ratio stations at Lucky Hills and Kendall watersheds Eddy covariance at Kendall watershed	1997 to 2007 2004 to present	Emmerich and Verdugo 2008 Scott et al. 2010

	Eddy covariance at Lucky Hills	2007 to present	Scott, 2010
Erodibility Erosion rate	Lab analysis ^{137}Cs analysis Lucky Hills and Kendall	Current state Average annual	Rhoton et al. 2007 Nearing et al. 2005
Satellite- and aircraft-based images of WGEW	Multiple sensors in the optical and microwave spectrum	1984 to present	Moran et al. 2008
Elevation, Watershed boundaries, streams, instrumentation, ecological sites, roads, land ownership, orthophotography	NA	Current state	Heilman et al. 2008
Soils, Geology and Geomorphology	NA	Current state	Osterkamp, 2008

The WGEW is also part of the growing network-within-a-network concept that is designed to coordinate long-term data collection across networks to address more science issues across larger spatial scales. WGEW is a site in a number of research networks that include both *in situ* and remotely sensed data sources (Table 2).

The impact of long-term, interdisciplinary data collection and research at WGEW on the current understanding of semiarid hydrology is evident (Renard et al., 2008). For example, the temporally continuous, spatially extensive WGEW precipitation database was used to develop the first depth-area-intensity relationships for semiarid convective airmass thunderstorms. WGEW was the site of the first quantification of transmission loss in ephemeral channels. The development and application of important prediction models have been based on parameterization and validation with WGEW data. This includes the KINEROS rainfall/runoff model and the USLE/RUSLE conservation planning technology (Renard et al., 2008). The WGEW Santa Rita flume with its traversing slot sampler is the first widely used technology to measure runoff and sediment transport in ephemeral streams. Experiments designed at WGEW with the rotating boom rainfall simulator have produced the world's largest database on rangeland hydrology and erosion.

4. DATA AVAILABILITY

The SWRC Data Access Project (DAP) provides public access to data collected at WGEW and SRER by SWRC (Nichols and Anson, 2008). The DAP currently supports access to long-term measurements of precipitation, runoff, sediment, meteorological conditions, soil moisture, temperature, vegetation, CO_2 flux and evapotranspiration (Table 1; Figure 3). The publicly accessible part of DAP consists of an interactive website (http://tucson.ars.ag.gov/dap), which provides an interface to the data and metadata, and a relational database to process, store, and manage data. After a user selects instrumented sites through a form based or graphical display, the site parameters are used to populate a standard form, and data are displayed in text, html, or Microsoft Excel formats. The files that make up the WGEW database are backed up to the main file server nightly. Each month, the entire database

Table 2. Long-term data collection networks co-located and/or cooperating with WGEW and providing public access to WGEW data.

Program	Mission	Sites	Web Site
Ameriflux network, established 1996	To provide continuous observations of ecosystem level exchanges of CO_2, water, energy and momentum spanning diurnal, synoptic, seasonal, and interannual time scales.	103 sites in North America, Central America, and South America; including 87 sites in the United States	http://public.ornl.gov/ameriflux/
USDA Natural Resources Conservation Service (NRCS) Soil Climate Analysis Network (SCAN), established 1991	To integrate information from existing soil-climate data networks and establish new collection points through partnerships with federal, state, local and tribal entities.	The current SCAN network includes hundreds of remote sites in 33 states and Puerto Rico.	http://www.wcc.nrcs.usda.gov/scan/
NASA Earth Observing System (EOS) Program, the first mission launched in 1997, the latest launched in 2006, and more planned	To provide systematic, continuous global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans from low Earth orbit for a minimum of 15 years.	25 Missions and Programs (http://eospso.gsfc.nasa.gov/eos_homepage/mission_profiles/index.php) with a series of satellites, a science component, and a data system	http://eospso.gsfc.nasa.gov/
Arizona Regional Image Access (ARIA), established in 1997	To provide digital image and map data for the Sonoran desert region, including the U.S. Southwest and northern Mexico.	ARIA serves over 2.0 TB of data online and users currently download approximately 50 scenes per day (see examples in Figure 4).	http://aria.arizona.edu
Global Fiducial Network, established in the 1990s	To build and maintain a long-term record of data to support scientists and policy makers, when such data can be publicly released.	There are 20 Global Fiducial Network sites within the conterminous United States.	http://gfl.usgs.gov/ see "Upper San Pedro Watershed East"
The EcoTrends Project, established in 2000	To promote and enable the use and synthesis of long-term data to examine trends in the Earth's ecosystems.	Includes data from 24 USDA experimental sites and more.	http://www.ecotrends.info

is written to a set of tapes and rotated to an offsite location. DAP maintenance requires continuing leadership, IT upgrades, limited data quality checking and maintenance of data loggers and instrumentation at a cost of about $20,000/year. The DAP online data access website has received over 24,000 visitors in the last 5 years.

Coincident with DAP was the SWRC development of the WGEW Image and Ground Data Archive (WIGDA). WIGDA is an archive of metadata that can be used to locate comprehensive sets of image and ground data files associated with remote sensing field campaigns at WGEW and the surrounding San Pedro River Basin over the past twenty years (see Figure 4 for examples). Interconnectivity with other data distribution systems is key to DAP success. The WIGDA database provided the metadata link between images and image-related ground data, but did not have capacity for interactive image downloading. To resolve this, the images identified by WIGDA were made available from University of Arizona, Arizona Regional Image Archive, or ARIA (http://aria.arizona.edu). The SWRC web site was linked to the ARIA web site to allow easy distribution of the selected images and the ARIA web site was revised to allow the WIGDA database to be downloaded directly from ARIA. Rather than support redundant data holdings, the DAP web site provides the GIS layers associated with ARIA spectral images, and conversely, the ARIA web site provides the DEM and DOQQ images associated with SRER and WGEW long-term measurements.

The DAP was designed for sustainability through the foreseeable future. That is, the data updating scheme is largely automated and can be accomplished with a small time investment from permanent staff. It is envisioned that permanent staff will continue to upgrade media, hardware and software as technology improves with time. The DAP web site was added to the American Geophysical Union (AGU) approved data sites based on criteria that "(1) access to data should be unrestricted and at reasonable or no cost, and that (2) the data centers should be committed to the permanent maintenance of data sets within their mandate" (http://www.agu.org/pubs/datacent.html).

5. Geographic Coverage

As part of a transition area between the Sonoran and Chihuahuan deserts WGEW contains vegetation with characteristics similar to large areas to the east, west and south. To the north, above the Mogollon Rim, the Colorado Plateau has a very different precipitation regime with much more precipitation as snow in the winter. Snow is a small part of the water budget on Walnut Gulch, although it is a major focus of study in the Reynolds Creek Experimental Watershed. Nor does the stream system of WGEW have a water table high enough to create streams with perennial flow, although the nearby San Pedro River has a number of perennial reaches. Land use on WGEW is also somewhat limited, as there is currently no irrigated agriculture.

The WGEW is the only long term experimental watershed situated in the hot desert region of North America. Of the 312 mm of annual precipitation in the 1956-2005 average, almost 60% of the precipitation fell in the July through September summer rainy season dominated by moisture from the Gulf of Mexico (Goodrich et al., 2008). This source of moisture drives the biological processes in the Chihuahua desert. On the other hand, winter moisture from the Pacific Ocean drives biological activity in the Sonoran Desert to the West. Because of these dual influences, the ecohydrology of WGEW is representative of a substantial region extending from the edge of the Mojave Desert in Southern California across the basin and range province to the western edge of the great plains in New Mexico and from the slopes of the Mogollon Rim in the north down along the eastern flank of the Sierra Madre Occidental into north-central Mexico.

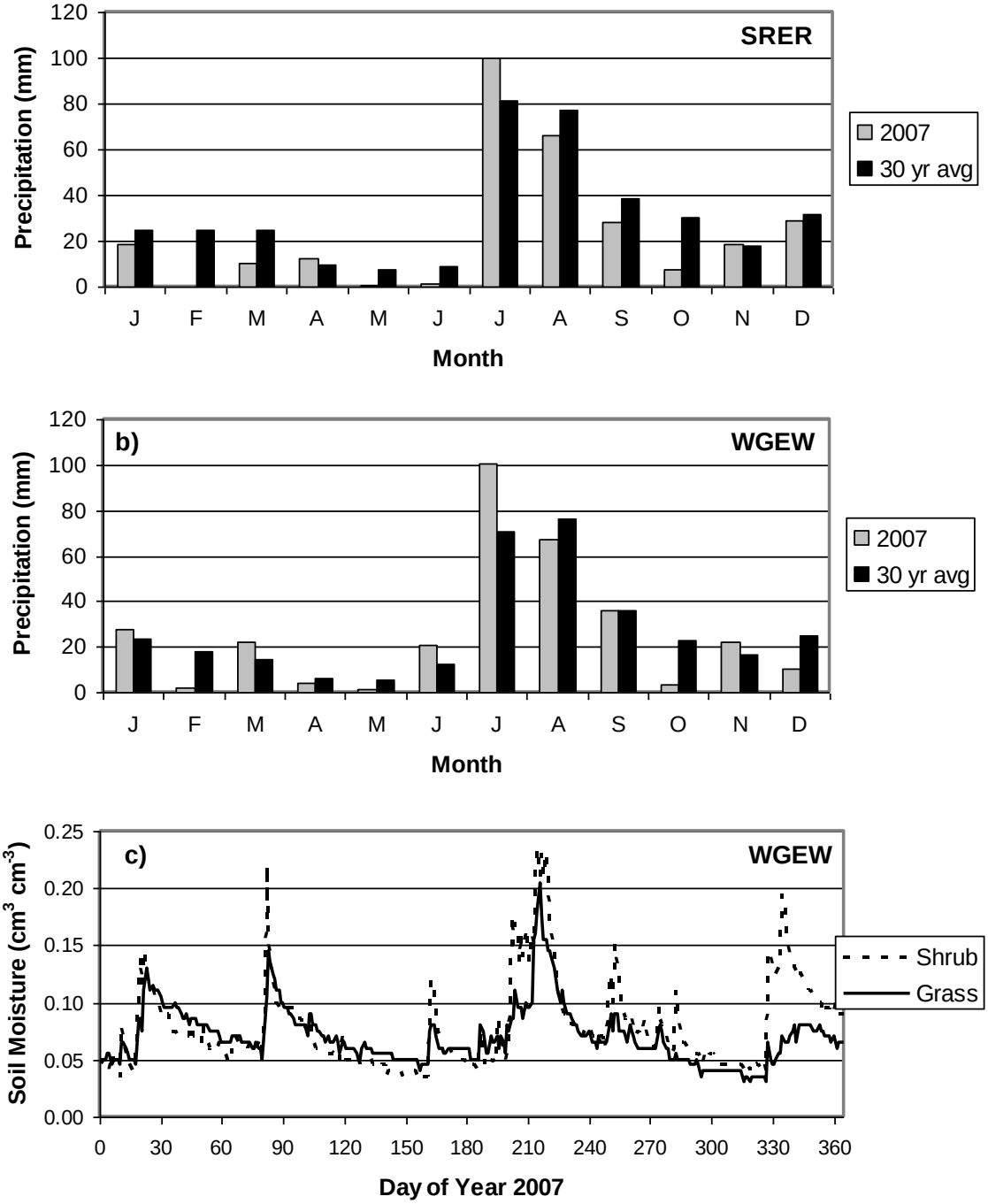

Figure 3. Examples of data available through SWRC DAP. Average monthly precipitation data compiled for multiple raingages in a) SRER and b) WGEW, for the 30-year time period encompassing most ARIA image acquisitions and year 2007; and c) the volumetric soil moisture to a depth of approximately 15 cm measured daily in WGEW in 2007 at shrub- and grass-dominated sites, illustrating the spatial variability induced by localized storms across the watershed. Figure from Moran et al. (2009).

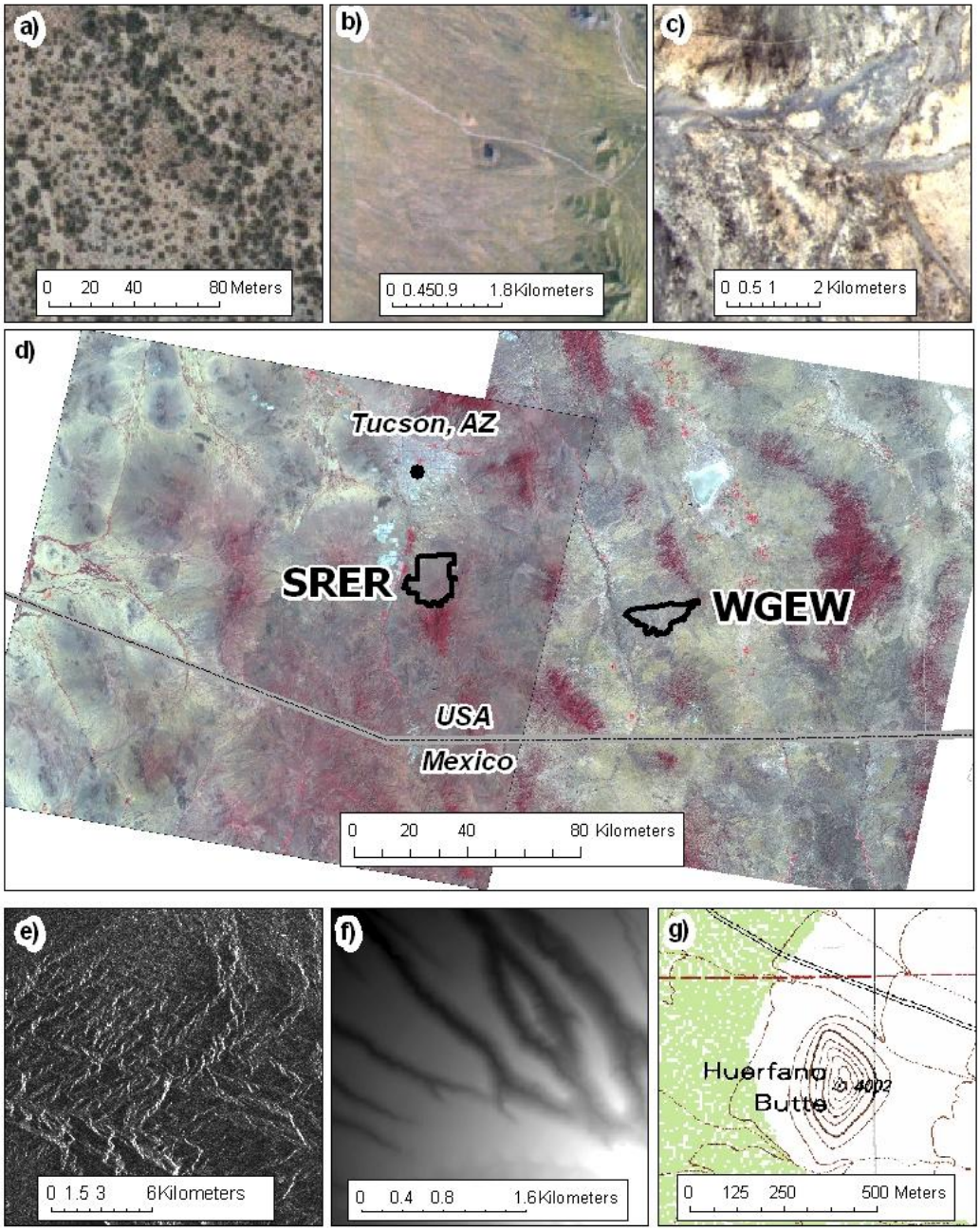

Figure 4. Location of WGEW and SRER with respect to Tucson, AZ, the US-Mexico border, and the footprints of two Landsat scenes (center panel (d)) with examples of imagery available from ARIA a) high spatial resolution (DOQQ), b) high spectral resolution (AVIRIS), c) multiband thermal imagery (MTI), e) synthetic aperture radar (ERS-SAR) as well as f) digital elevation models (DEMs) and g) topographic maps (DRGs). Figure from Moran et al. (2009).

Figure 5 shows both the WGEW and SRER locations within two vegetation classification maps. The most restrictive geographic classification is the Natural Resource Conservation Service's (NRCS) Major Land Resource Areas (MLRAs). The total area of the 4 MLRAs in the US in Figure 5 is about 320,000 km^2. The NRCS classification containing most of both WGEW and SRER, shown in blue (left figure), is Common Resource Area (CRA) 41-3, Semidesert Grasslands. Annual average precipitation in CRA 41-3 is in the 300-400 mm (12-16 in) range. Within CRA 41-3, the NRCS has defined 22 ecological sites that are capable of producing the same vegetation community for rangeland management purposes. WGEW has 12 of those 22 ecological sites (Heilman et al., 2010), as well as 2 of the 17 ecological sites defined in the next higher precipitation zone (400-500 mm, Mexican Oak-Pine Forest and Oak Savannah). MacEwen et al. (2005) mapped MLRA 41 into the Mexican states of Sonora and Chihuahua. The adjacent MLRAs, 38 - Arizona Interior Chaparral, 40 - Sonoran Basin and Range, and 42 - Southern Desertic Basins, Plains and Mountains, are capable of producing shrublands and grasslands similar to those found on WGEW depending on elevation and aspect. A second commonly used vegetation classification shown in Figure 5 is the Omernik Level II map with WGEW falling in Ecoregion 12.1, Western Sierra Madre Piedmont, also shown in blue (right figure). The two adjoining similar areas to the east and west are mapped as Ecoregion 10.2, Warm Deserts (http://www.epa.gov/wed/pages/ecoregions/na_eco.htm#Level%20II). The area of Ecoregion 10.2 and 12.1 in the US is about 450,000 km^2.

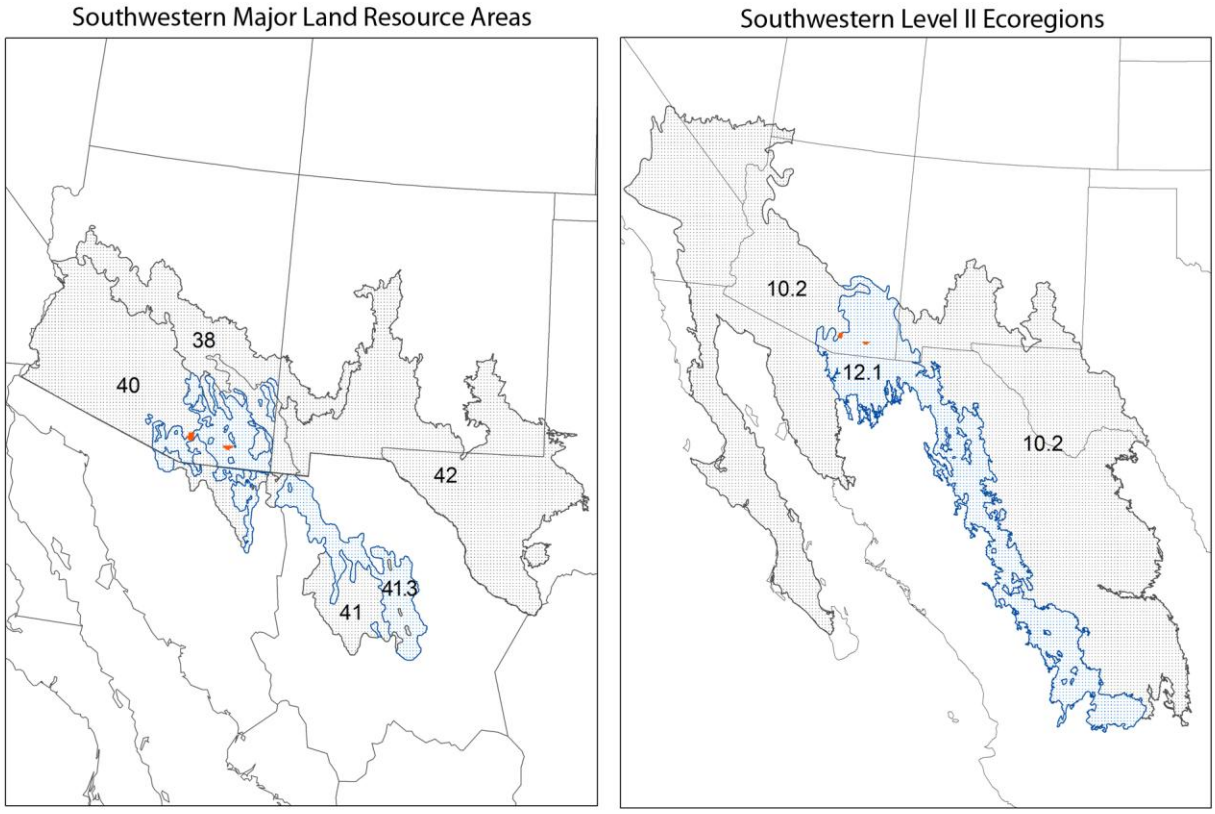

Figure 5. Two commonly used vegetation classification approaches are the NRCS Major Land Resource Areas with a focus on agriculture (left), and the more general Level II Ecoregion classification by Omernik (right).

The National Ecological Observatory Network (NEON) region #14 (Desert Southwest) is roughly congruent with the combined grey and blue areas of the Omernik classification on the US side of the international border shown in Fig. 5, and contains both the WGEW and SRER. The SWRC's presence was

an important factor in the selection of SRER as a core site and data from our metflux towers have already been used in the design of NEON's core instrumental units. Furthermore, SWRC's long history of research results from the SRER are essential to defining NEON's future research challenges. In the 10 Major Farm Region division of the US, WGEW is on the southern edge of the Mountain Region. WGEW is in HUC-2 Region 15 (Lower Colorado) draining to the Gila River, the Colorado River, and, under ideal conditions, ultimately to the Gulf of California. WGEW has its own 12 digit HUC code (150502020607), although there is a small area between the outlet of the WGEW at Flume 1 and the confluence of Walnut Gulch and the San Pedro River that is not within the boundaries of WGEW.

6. Partnerships

The SWRC has a history of supporting research, education, and outreach through long-term collaborative relationships with local, regional, and international partners. Although the decision to establish the (WGEW) in the area surrounding Tombstone AZ was primarily based on the physical attributes of the watershed, cooperation and support of local ranchers was a critical consideration. At the time the watershed was established as a research site, a major objective was to determine if conservation practices would affect water yields and sediment movement, which was a topic of direct concern to both local ranchers and downstream inhabitants. Cooperation with local ranchers continues to play an important role in managing WGEW as a research watershed. However, as ranches change hands and the population increases, on-the-ground interactions are shifting to a broader, non-ranching community.

Water yield and supply concerns continue to be important drivers of science, management, and policy. These concerns increasingly are recognized as components of complex ecohydrologic systems that require broader interdisciplinary approaches to scientific understanding. Currently, research on the WGEW plays a critical role in science based decision making in the larger San Pedro Watershed through the Upper San Pedro Partnership (USPP). The USPP consists of twenty-one member agencies and organizations including government and non-governmental organizations, elected officials, and residents. Research conducted on the WGEW has been and is being used to answer specific research questions, such as the role of vegetation in the water balance of the San Pedro Basin and the effects of urbanization of water redistribution patterns. In addition to the USPP, SWRC scientists advise numerous local and state organizations including the Malpai Borderlands Group, Hay Mountain Watershed Group, Upper Eagle Creek Watershed Group, Ranching Heritage Alliance, Community Watershed Association, Appleton Whittell Research Ranch, Las Cienegas National Conservation Area, Fort Huachuca, Arizona State Technical Committee and Arizona Coordinated Resource Management Technical Committee. The SWRC has a particularly strong link with the NRCS, both in Arizona and nationally. Agencies with national responsibilities that collaborated with the SWRC to the extent of providing funding in 2011 include the National Park Service, National Aeronautics and Space Administration, Environmental Protection Agency, Department of Defense and the NRCS.

The SWRC also has a long history of partnership and collaboration with local, national, and international universities. The SWRC is a strong partner with the University of Arizona to accomplish education and outreach activities. The scientific staff at SWRC serves as adjunct professors in the Hydrology, Soil Water and Environment, Agriculture and Biosystems Engineering, and the School of Natural Resources and the Environment. Through these relationships SWRC scientists compete for funding, serve on graduate committees, mentor students through the NASA Space Grant Consortium, and provide research experience for undergraduate students. SWRC also partners with Cooperative Extension personnel at the University of Arizona to support and education and outreach goals. International collaboration

includes formal and informal projects with Mexico, Spain, Switzerland, Italy, Belgium, Kazakhstan, and China as well as hosting visiting scientists, students and post docs.

Of the ARS locations that will potentially form the initial LTAR, the SWRC partners most closely with the Jornada Experimental Range in New Mexico and the Northwest Watershed Research Center (NWRC) in Idaho. The focus of research at the Jornada, ecological processes in the Chihuahuan Desert, complements soil and water research at SWRC. Collaborations include remote sensing of vegetation and soil moisture, quantification of management effects on rangeland health, the Rangeland Conservation Effects Assessment Project, and tools to help rangeland managers. The NWRC manages the Reynolds Creek Experimental Watershed. Collaboration between the NWRC and SWRC includes leadership on ARS watershed model integration, the development of the Rangeland Hydrology and Erosion Model (RHEM), and support of the Rangeland Conservation Effects Assessment Project. The SWRC and NWRC constitute the core of the ARS rangeland watershed research program.

7. Institutional Commitment

The SWRC has operated the WGEW for almost 60 years. As the SWRC's outdoor laboratory, the WGEW is the heart of the research unit and the focus of efforts to develop a scientific understanding of watershed processes. In arid and semiarid environments, long-term (multidecadal) studies are needed to understand the effect of extreme events on the fundamental processes related to soil and water conservation (Nearing et al., 2007). Given the existing long-term data record, ongoing collaborations, and the need to understand the response of natural systems to changes in both climate and management, it is safe to say that, as long as the SWRC exists, WGEW will be intensively monitored. However, given the state of the federal budget, one cannot make long term commitments to specific data collection efforts. The support of ARS Pacific West Area Director, Andrew Hammond, for SWRC participation in LTAR is documented in Appendix A.

There is strong evidence that SWRC scientists are committed to integrating the understanding gained from the WGEW into the context of its surrounding landscape, across disciplines, and together with insight from other intensively monitored research sites. That evidence includes:

- The 3 trans-disciplinary experiments focused on WGEW discussed in Section 1
- The 3 larger trans-disciplinary collaborations focused on the Upper San Pedro Basin also discussed in Section 1
- Participation in the 6 long-term research networks listed in Section 3, Table 2
- WGEW data is documented in a special issue of Water Resources Research, which required being listed as an AGU approved data site (as described in Section 4)

In addition:

- SWRC scientists founded the Interagency Conference on Research in the Watersheds (ICRW) series and hosted the inaugural (2003) ICRW Conference in the San Pedro Basin in Benson, Arizona
- SWRC scientists have actively fostered collaboration between ARS watersheds (Goodrich et al., 1994; Goodrich et al., 2011)
- SWRC scientists led the initial steps in the systematic analysis of an informal group of 12 ARS, Forest Service, and university grassland research sites (Moran et al., 2008; Ponce et al., 2011)

The SWRC appreciates the benefits of standardization, although some of the unique conditions required the development of instrumentation specifically designed for conditions of the southwest (such as the Santa Rita supercritical flow flumes). Thus, there may be some limitations to the extent with which our measurements can be used with procedures designed for Eastern and Midwestern cropland conditions. The SWRC agrees to participate in annual meetings and to contribute to ongoing network activities and initiatives, as well as to undergo a formal review process every five years. Lastly, we welcome research partners from other areas ARS locations and from outside the ARS. Collaborators will need to understand that as the SWRC does not own any of the land in WGEW, so any new experiments that would result in large-scale land disturbance need to be approved by the affected land owners. The SWRC is willing to help write proposals for additional research funding to support collaborative research. Addressing critical long-term regional and national scale resource problems will require increased collaboration across the country's outdoor laboratories. The SWRC is committed to integrating the knowledge gained on the WGEW to a broader understanding of the interaction of climate and management on soil and water in the semiarid southwest. For that reason, the SWRC requests consideration of the WGEW as a founding member of the Long-Term Agroecological Research network.

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Appendix A

From: Hammond, Andrew
Sent: Tuesday, November 08, 2011 10:10 AM
To: Heilman, Phil
Cc: Matteri, Robert; Whalen, Maureen
Subject: Support for participation in LTAR

Because a strength of ARS research is the ability to conduct long-term research and a core area of ARS's research mission is natural resources and environment, I support the participation of the ARS, Southwest Watershed Research Center, Tucson, Arizona, in ARS's Long-Term Agro-Ecosystem Research Network (LTAR) contingent on annual appropriations and the research priority setting process.

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