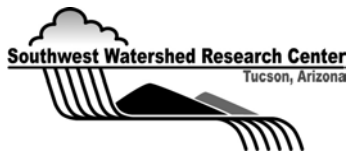


WALNUT GULCH EXPERIMENTAL WATERSHED

TOMBSTONE, ARIZONA



MISSION STATEMENTS

United States Department of Agriculture (USDA)

USDA Mission: Enhance the quality of life for the American people by supporting production of agriculture:

- ensuring a safe, affordable, nutritious, and accessible food supply
- caring for agricultural, forest, and range lands
- supporting sound development of rural communities
- providing economic opportunities for farm and rural residents
- expanding global markets for agricultural and forest products and services
- working to reduce hunger in America and throughout the world.

Agricultural Research Service (ARS)

ARS Mission: Conduct research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to

- ensure high-quality, safe food and other agricultural products
- assess the nutritional needs of Americans
- sustain a competitive agricultural economy
- enhance the natural resource base and the environment
- provide economic opportunities for rural citizens, communities, and society as a whole.

Southwest Watershed Research Center (SWRC)

SWRC Mission: Conduct research to

- quantify, understand and model the effects of changing climate, land use and management practices on the hydrologic cycle, carbon cycle, soil erosion processes, and watershed resources
- conduct integrated systems research for the development of new technology to predict and assess the condition and sustainability of rangeland watersheds and for the development of decision support tools for natural resource models
- operate the Walnut Gulch Experimental Watershed which serves as an “outdoor laboratory” where detailed experiments and observations are conducted to improve our basic understanding of semi-arid rangeland
- extend scientific findings beyond gauged experimental watersheds and to facilitate technology transfer of knowledge, research data, interpretations, natural resource models and decision support tools to stakeholders, decision-makers and the public.

RESEARCH PROGRAM AREAS

Walnut Gulch Experimental Watershed is the outdoor laboratory which supports SWRC field studies on natural and managed ecosystems to fulfill the research goals and objectives of the scientific program. Research at the Southwest Watershed Research Center is conducted in 5 major program areas.

1. Hydrologic Processes

Investigate hydrologic processes and related variability to understand water supply, water quality, and energy fluxes from managed and natural semi-arid watersheds. Integrate interdisciplinary field experiments, simulation models, remote sensing and geographic information systems (GIS) to improve our databases and our understanding of the impacts of natural and managed change on semi-arid watersheds.

2. Erosion and Sedimentation

Determine upland and channel erosion and sedimentation processes and their impact on water quality, semi-arid landscape evolution and the health and sustainability of rangeland ecosystems. Determine the rate of soil loss an ecosystem can endure and still remain economically and ecologically sustainable. Improve water erosion prediction technology to preserve and increase land productivity and prevent water degradation.

3. Global Climate Change and CO₂ Fluxes

Evaluate rangelands as a source or sink of carbon in the global carbon budget and to develop an understanding of their role in global climate change. Determine carbon dioxide sequestration and plant water use efficiency of grass and shrub communities. Investigate modeling and scaling related to global change issues in semi-arid rangelands.

4. Remote Sensing

Employ radiometers mounted on aircraft or satellite platforms to monitor temporal changes in Earth characteristics. Conduct sensor calibration and signal processing. Map biophysical information, such as evaporation, soil moisture and forage production. Develop simulation models driven by remotely sensed data to monitor daily plant and soil conditions for range management.

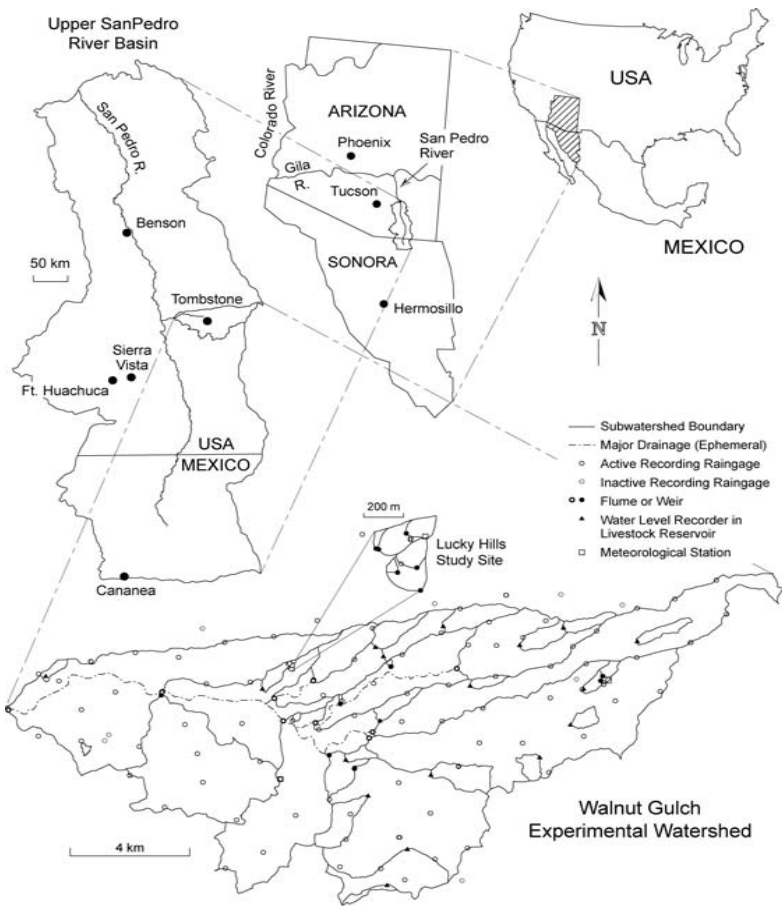
5. Decision Support Systems

Develop computer-aided decision-making tools and systems that incorporate science into the decision making process. Develop integrated information systems that combine decision tools, databases, models and expert opinion for improved management of semi-arid watersheds. Transfer knowledge and technology to stakeholders, decision-makers and the public.

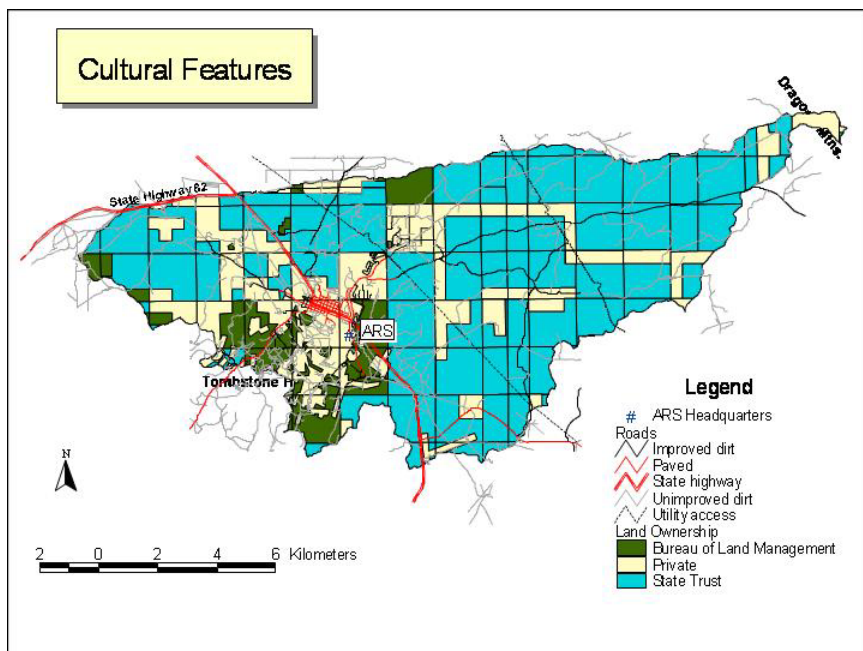
WALNUT GULCH EXPERIMENTAL WATERSHED

Description

The Walnut Gulch Experimental Watershed encompasses the 150 square kilometers in southeastern Arizona, U.S.A. ($31^{\circ}43'N$, $110^{\circ}41'W$) that surrounds the historical western town of Tombstone. The watershed is contained within the upper San Pedro River Basin which encompasses 7600 square kilometers in Sonora, Mexico and Arizona. The watershed is representative of approximately 60 million hectares of brush and grass covered rangeland found throughout the semi-arid southwest and is a transition zone between the Chihuahuan and Sonoran Deserts. Elevation of the watershed ranges from 1250 m to 1585 m MSL. Cattle grazing is the primary land use with mining, limited urbanization, and recreation making up the remaining uses. Walnut Gulch, being dry about 99% of the time, is an ephemeral tributary of the San Pedro River.



Location of Walnut Gulch Experimental Watershed



Walnut Gulch Experimental Watershed and the vicinity of Tombstone, Arizona



Walnut Gulch Experimental Watershed Field Office

History

The Walnut Gulch Experimental Watershed was selected as a research facility by the United States Department of Agriculture (USDA) in the mid-1950's. Prior appropriation water laws resulted in conflicts between upstream land owner conservation programs and downstream water users. Technology to quantify the influence of upland conservation on downstream water supply was not available. Thus, scientists and engineers in USDA selected the Walnut Gulch watershed for a demonstration/research area which could be used to monitor and develop technology to address the problem. In 1959, facilities needed for soil and water research in the USDA were identified in a United States Senate document. This report created the national program of USDA-ARS research on soil and water processes. The Southwest Watershed Research Center in Tucson, Arizona was created in 1961 to administer and conduct research on the Walnut Gulch Experimental Watershed. Subsequent legislation (Clean Water Legislation of the 1970's) added water quality thrusts to the research program.

Research at the Southwest Watershed Research Center, and specifically on the Walnut Gulch Experimental Watershed, is currently conducted within the definitions of the Agricultural Research Service's National Programs. There are 22 National Programs in three categories. All SWRC research conducted at the watershed is under the purview of 4 National Programs within the category Natural Resources and Sustainable Agricultural Systems. The 4 programs with Walnut Gulch Experimental Watershed research contributing to them are: Water Quality and Management; Rangeland, Pasture and Forage; Global Change; Integrated Agricultural Systems.

Walnut Gulch Experimental Watershed is also a partner in the ARS Experimental Watersheds and Watershed Program. Fourteen ARS research centers are operating over 100 long-term research watersheds. These exceptional outdoor laboratories make major contributions to national scale projects including GEWEX, AMERIFLUX, ARS Rangeland Carbon Flux, USDA-NRCS Soil Climate Analysis Network (SCAN), and the Surface Radiation Network (SURFRAD).

The long-term data bases and substantial infrastructure of the Walnut Gulch Experimental Watershed have attracted collaborative efforts with other federal and state agencies, universities, and foreign researchers. Collaborative research efforts have included ARS Hydrology Laboratory, ARS Water Conservation Laboratory, ARS Jornada Experimental Range, USDA Natural Conservation Research Service, US Geologic Survey, NASA, Arizona Department of Water Resources, Cochise County, University of Arizona, Arizona State University, and researchers from Mexico, Australia, Europe, Africa, and Asia.

Walnut Gulch Experimental Watershed is one of two ARS experimental watersheds on western rangelands and the only one on southwest semi-arid rangelands. Walnut Gulch Experimental Watershed has developed a reputation as the leading semi-arid research watershed in the world. The land comprising Walnut Gulch Experimental Watershed is under the ownership and control of Federal agencies, State of Arizona, private land owners or leaseholders. The research activities and access to the field sites are arranged in cooperation with the appropriate federal and state agencies and the private landowners or leaseholders.

SWRC has designed and developed instrumentation to specifically measure and monitor the hydrology of these semi-arid rangelands and has used this instrumentation to develop extensive, world renowned databases of the hydrology of semi-arid rangelands. From these sources SWRC scientists have produced over 1500 manuscripts and several computer simulation models so that the hydrologic knowledge gained can be transferred

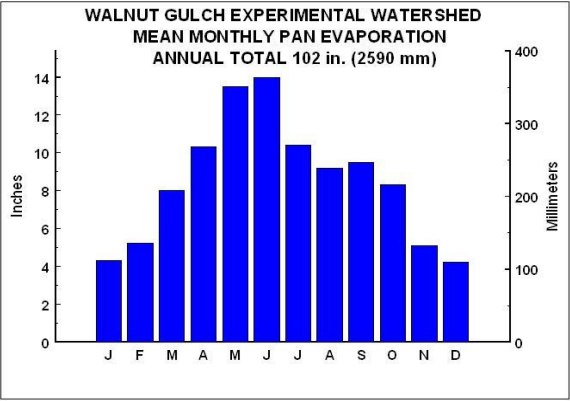
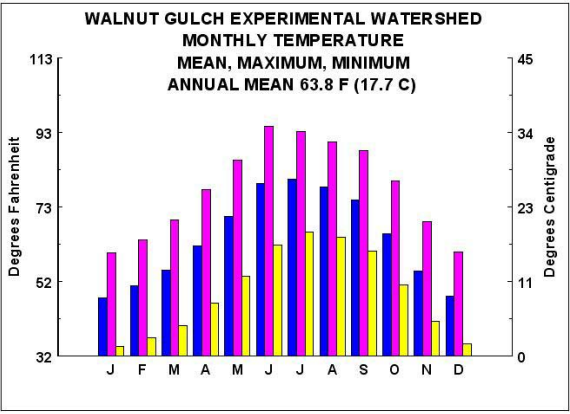
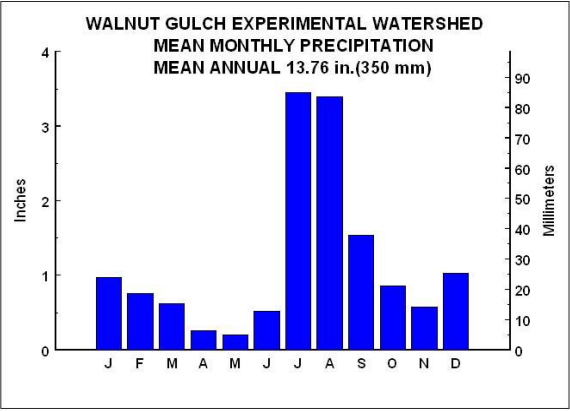
to a variety of users. Some of the hydrologic models developed, in whole or in part, include CREAMS, RUSLE, WEPP, KINEROS, EPIC, SPUR and CLIMATE. A complete list of publications, models and databases is available from the SWRC.

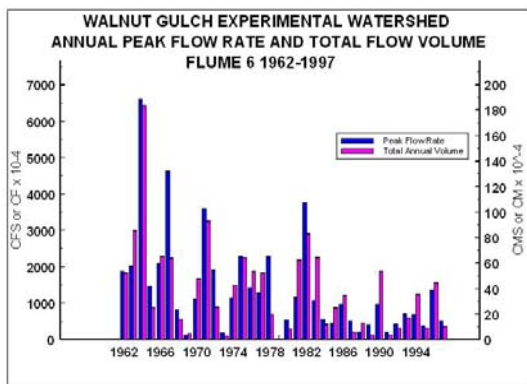
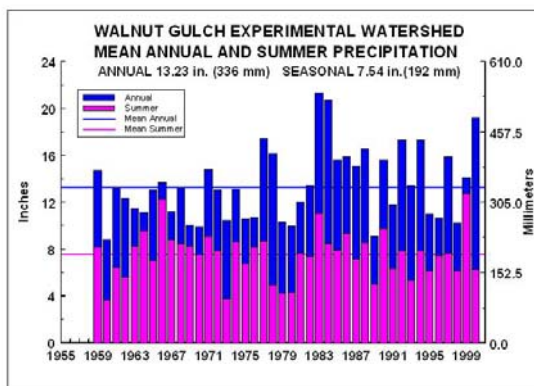
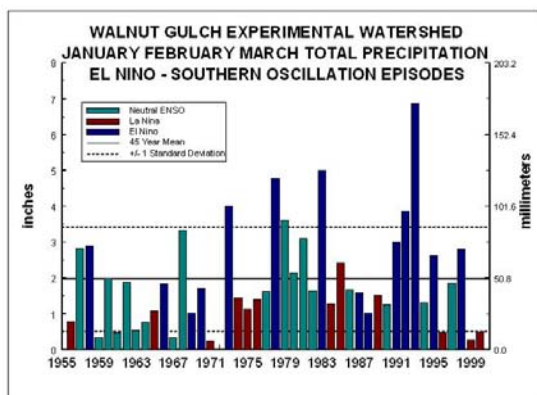


Construction of Flume 1, 1964.

Climate

Walnut Gulch Experimental Watershed lies in the transition zone between the Sonoran and the Chihuahuan Deserts. The climate is classified as semi-arid, with mean annual temperature at Tombstone of 17.7°C and mean annual precipitation of 350 mm. On average there are 53 days of precipitation per year and most accumulation is as rainfall. The precipitation regime is dominated by the North American Monsoon with slightly more than 60% of the annual total coming during July, August and September; about 1/3 coming during the six months October through March. Summer events are localized short-duration, high-intensity convective thunderstorms driven by the intense solar heating of the land surface and moisture inputs from the Gulf of Mexico and Gulf of California. Winter storms are generally slower moving, frontal systems from the Pacific Ocean. These frontal systems generate longer duration and lower intensity precipitation that covers larger areas. The two opposite phases of the ocean-atmosphere phenomenon El Nino-Southern Oscillation (ENSO), referred to as El Nino and La Nina, affect winter precipitation with greater than normal precipitation during El Nino periods and less than normal precipitation during La Nina episodes. Virtually all runoff is generated by summer thunderstorm precipitation and runoff volumes and peak flow rates vary greatly with area and on an annual basis.





Geology

The Walnut Gulch Experimental Watershed is located primarily in a high foothill alluvial fan portion of the larger San Pedro River watershed. Cenozoic alluvium is very deep and is composed of coarse-grained fragmentary material, the origin of which is readily traceable to present-day mountain flanks on the watershed. The alluvium consists of clastic materials ranging from clays and silts to well-cemented boulder conglomerates with little continuity of bedding. This alluvial fill material is more than 400 m deep in places and serves as a huge ground water reservoir. Depth to ground water varies greatly in the watershed ranging from 50 m at the lower end to 145 m in the central parts of the watershed. Topographic expression of the alluvium is that of low undulating hills dissected by present stream channels whose routes are controlled by geologic structures. Upland slopes can be as great as 65% while slopes in the lower lying areas can be as small as 2 to 3%. Major channel slopes average about 1% with smaller tributary channels averaging 2 to 3%.

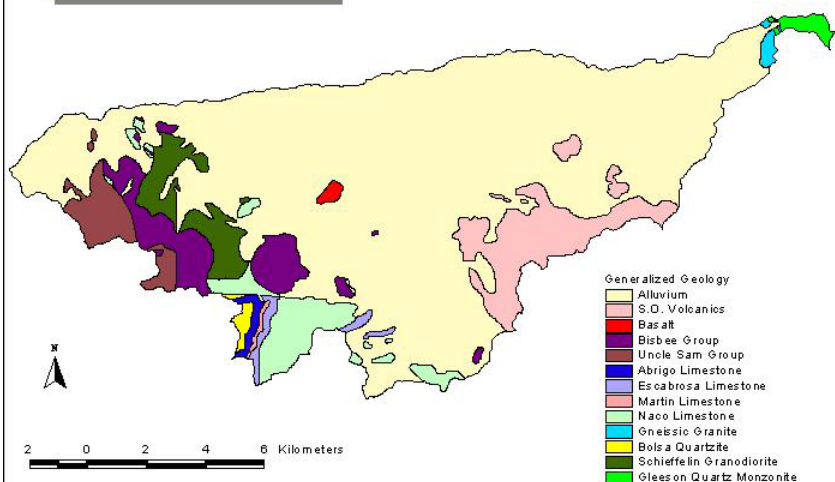
The remaining mountainous portion of the watershed consists of rock types ranging in age from pre-Cambrian to Quaternary, with rather complete geologic sections. Rock types range from ridge-forming limestone to weathered granite intrusions. The geologic structural picture of the mountainous area is complex, with much folding and faulting. This folding and faulting, along with igneous intrusions has resulted in large areas of shattered rock, which influence the watershed hydrology.

The watershed hydrology is, in places, controlled by past geologic events and structures. Intrusive igneous dikes in the Tombstone Hills influence ground water movement and change the surface drainage. The Schieffelin granodiorite alters the course of the Walnut Gulch main stream, acts as a probable ground water barrier between the ground water in the Tombstone Hills and the deep alluvial basin, and has caused numerous small perched water tables along its perimeter. Highly compacted conglomerate beds greatly alter the path of stream channels and, in places, divert streams at more than right angles. High angle faults form new paths for streamflow, making channels arrow-straight in some places and causing diversions in others.

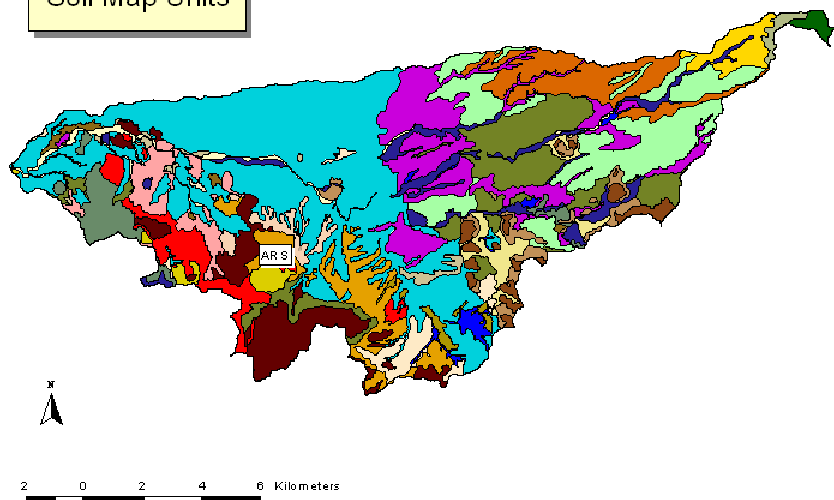
Soils

Soils on the Walnut Gulch Experimental Watershed reflect the geologic parent material from which they developed. The limestone influenced alluvial fill parent material is dominant on the watershed. The soils that developed from this material are generally well drained, calcareous, gravelly loams with large percentages of rock and gravel at the soil surface. Soil surface rock fragment cover (erosion pavement) can range from nearly 0% on shallow slopes to over 70% on the very steep slopes. NRCS has mapped 27 soil series on the watershed. The major soil series presently defined on this area are Blacktail (fine, mixed, thermic, Aridic Argistolls), McAllister (fine-loamy, mixed, thermic, Ustollic Haplargids), Elgin (fine, mixed, thermic, Ustollic Paleargids), Sutherland (loamy-skeletal, carbonatic, thermic, shallow Ustollic Paleorthids), Monterosa (loamy-skeletal, mixed, thermic, shallow Ustollic Paleorthids), Stronghold (coarse-loamy, mixed, thermic, Ustollic Calciorthids), Luckyhills (coarse-loamy, mixed, thermic, Ustochreptic Calciorthids). The uppermost 10 cm of the soil profiles contain up to 60% gravel, and the underlying horizons usually contain less than 40% gravel. The remaining soils developed from igneous intrusive materials and are generally cobbly, fine textured, shallow soils.

Generalized Geology



Soil Map Units



Vegetation

Although historical records indicate that most of the Walnut Gulch Experimental Watershed was grassland approximately 100 years ago, shrubs now dominate the lower two-thirds of the watershed. Major watershed vegetation includes the shrub species of creosote bush (*Larrea tridentata*), white-thorn (*Acacia constricta*), tarbush (*Flourensia cernua*), snakeweed (*Gutierrezia sarothrae*), and burroweed (*Aplopappus tenuisectus*); and grass species of black grama (*Bouteloua eriopoda*), blue grama (*B. gracilis*), sideoats grama (*B. curtipendula*), bush muhly (*Muhlenbergia porteri*), and Lehmann lovegrass (*Eragrostis lehmanniana*). Shrub canopy cover ranges from 30 to 40% and grass canopy cover ranges from 10 to 80%. Average annual herbaceous forage production is approximately 1200 kg/ha.



Shrub dominated lower part of watershed.



Grass dominated upper part of watershed.

Precipitation

Precipitation varies considerably from season to season and from year to year on the Walnut Gulch Experimental Watershed. Annual precipitation varied from 170 mm in 1956 to 541 mm in 1983; summer rainfall (July, August and September) varied from 93 mm in 1960 to 325 mm in 1999; and winter precipitation (January, February and March) varied from 0 mm in 1972 to 175 mm in 1993. Approximately two-thirds of the annual precipitation on the Walnut Gulch Experimental Watershed occurs as high intensity, convective thunderstorms of limited areal extent. The moisture source for these thunderstorms is primarily the Gulf of Mexico and the Gulf of California.

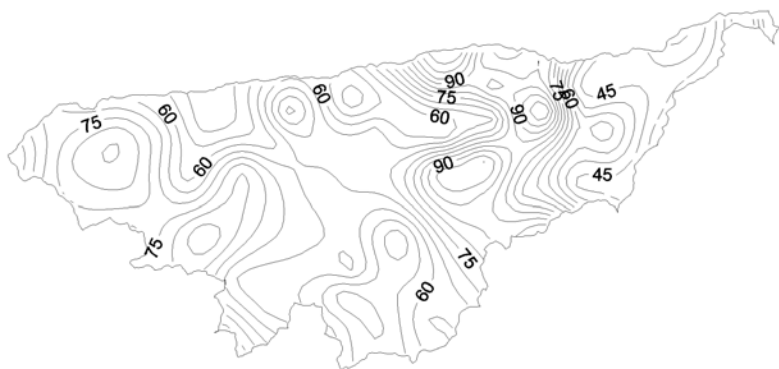
Winter rains (and occasional snow) are generally low-intensity events associated with slow-moving cold fronts, and are generally of greater areal extent than summer rains. Convective storms can occur during the winter as well. Runoff on the Walnut Gulch Experimental Watershed results almost exclusively from convective storms during the summer season.

Summing individual storm events to generate monthly and seasonal values for precipitation illustrates some water supply and forage management problems. The ensemble of individual storm events such as that shown below for August 27, 1982 resulted in the following August isohyetal map. The ratio of maximum point precipitation of 90 mm to the minimum of 45 mm (a ratio of 2:1) has been measured with considerable regularity. But more importantly, although these extremes were only 4 km apart, they occurred in the same pasture of one ranch. The maximum rainfall value produced good forage whereas the minimum rainfall produced less than normal forage.

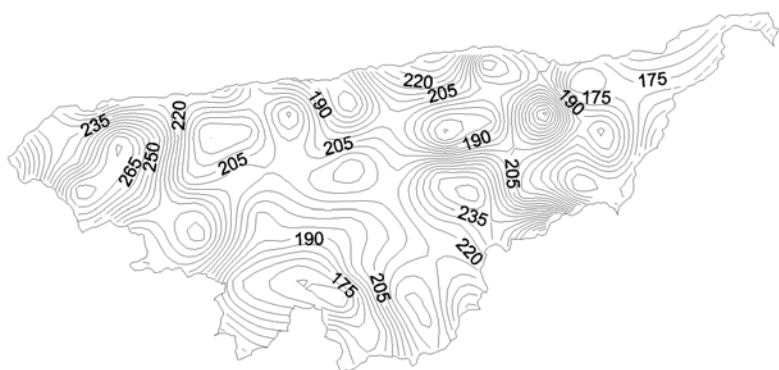
The precipitation variability during the summer season when most forage production occurs in the Walnut Gulch Experimental Watershed is indicated. Again, the variability is appreciable with the amounts of 240 mm and 170 mm being less than 5 km distant. Spatial precipitation variability is proportionally ameliorated by non-summer rains in either the early year (January-March) or late in the calendar year (October-December). Both seasons' precipitation can provide antecedent moisture for early season forage grasses.



Precipitation (mm) Storm Event August 27, 1982



Precipitation (mm) August 1982



Precipitation (mm) Summer 1982



Precipitation (mm) Total 1982

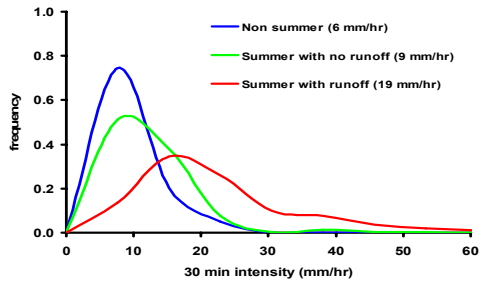
Runoff

Runoff at the Walnut Gulch Experimental Watershed is typical of many semi-arid regions in that the channels are dry for most of the year. Runoff only occurs as the result of rainfall and the hydrographs are "flashy" meaning that the flood peak arrives very quickly after the start of runoff and the duration of runoff is short. Almost all of the annual runoff and all of the largest events occur between July and September as a result of high intensity, short duration, and limited areal extent thunderstorms. Runoff occurs very infrequently in the early fall as a result of tropical cyclones and in the winter as a result of slow moving frontal systems both of which cover large areas and have rainfall of low intensities and long durations.

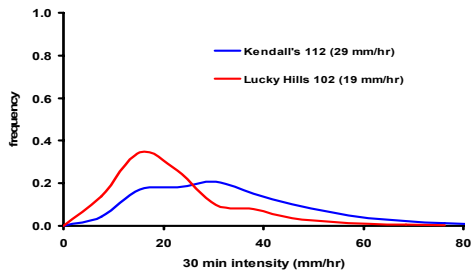
Although these fall and winter rainfall events generate little runoff at the Walnut Gulch Experimental Watershed, this is not the case for the San Pedro River just downstream from where Walnut Gulch enters the river. For the same period of record (1963-1996), the top six annual maximum peak flow events at the outlet of the Walnut Gulch Experimental Watershed occurred in the summer months, while for the San Pedro, two of the top six occurred in the fall and two occurred in the winter.

Watershed size or scale plays an important role on the dominant processes determining runoff characteristics. At the hillslope scale, the rates and amounts of runoff are influenced by rainfall intensity and soil-vegetation characteristics. Runoff occurs when the rainfall intensity is greater than the infiltration capacity of the soil, a process referred to by hydrologists as rainfall excess or "Hortonian Flow". The importance of rainfall intensity in the generation of runoff can be illustrated by plotting the frequency of the maximum 30 minute rainfall intensity for rainfall events in the non-summer months, for events in the summer months that do not produce runoff, and for events in the summer months that do produce runoff. As can be seen, the average 30 minute intensity for the summer runoff producing rainfall is twice and three times as large than for the non runoff producing summer and winter rainfall events respectively. The influence of the interaction between rainfall intensity and soils and vegetation can be illustrated by comparing the frequency of runoff producing summer events between the Lucky Hills shrub dominated watershed 102 and the Kendall's grass dominated watershed 112. In this case the average 30 minute intensity is 10 mm/hr greater for the Kendall's watershed meaning that it takes higher rainfall intensities to produce runoff on the grassed watershed. In contrast to runoff at the hillslope scale, runoff at the watershed scale is controlled more by infiltration of water into the alluvial channels (transmission losses) and the spatial distribution of thunderstorm rainfall. The result of these two factors leads to a decrease in unit runoff depth and peak discharge with increasing area.

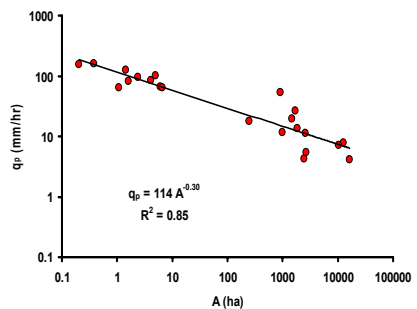
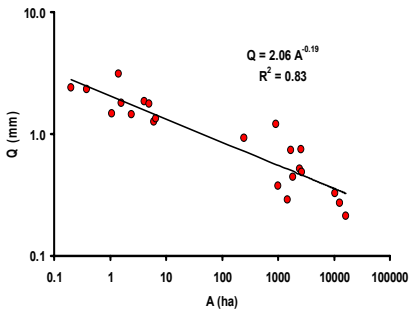
The runoff data from the Walnut Gulch Experimental Watershed have been used for flood frequency analysis, water yield estimations, and validation of hydrologic and sediment yield models. Current uses of the data include small and large scale water balance estimates, runoff and sediment yield linkages with the Upper San Pedro River Basin, and validation of remote sensing algorithms and simulation models integrated with Geographic Information Systems.



A comparison of the frequency of 30 minute rainfall intensity for events during the periods of non summer, summer with no runoff, and summer with runoff for Lucky Hills 102. Value in parenthesis is the average 30 minute intensity.



A comparison of the frequency of 30 minute rainfall intensity for events during the summer with runoff for a grass (Kendall's) and a shrub (Lucky Hills) dominated watershed. Value in parenthesis is the average 30 minute intensity.

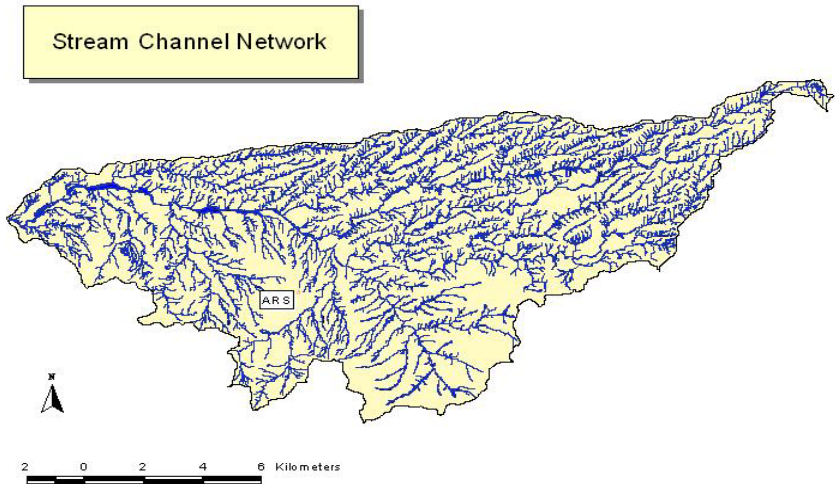


Relationship between average event runoff, Q , (left) and maximum peak discharge, q_p , (right) with watershed area, A , for the period of record 1963-1996.

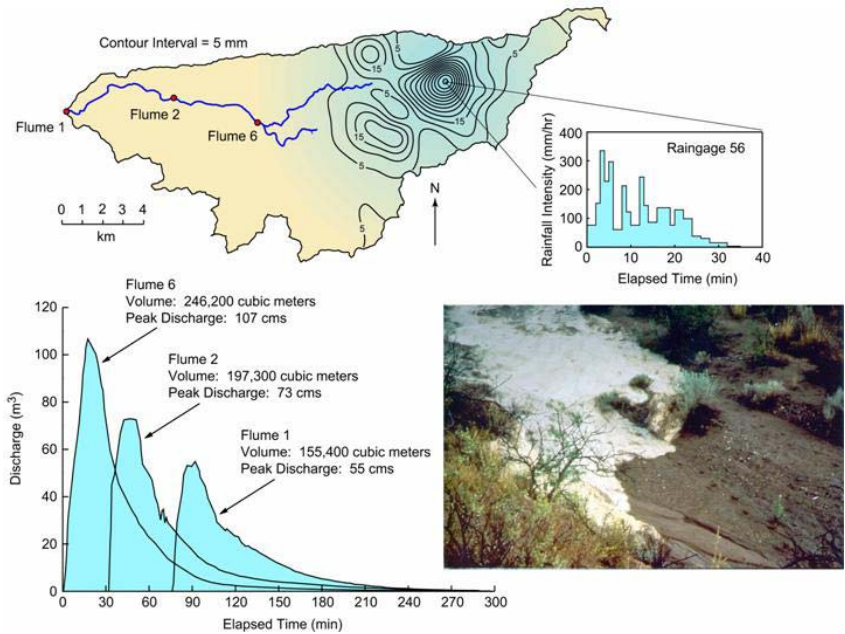
Runoff Transmission Losses

In semi-arid areas such as the Walnut Gulch Experimental Watershed, ranching, wildlife, increasing populations, urbanization, expanding industry, and needs of downstream water users all compete for limited water resources. The increased demand for water resources creates pressure to develop new sources of water and requires better methods of quantifying the water budget; assessing streamflow; and assessing the interaction between streamflow, flooding, infiltration losses in channel beds and banks, evapotranspiration, soil moisture, and ground water recharge.

An important component of the Walnut Gulch Experimental Watershed water budget is streamflow abstraction from infiltration in the channel beds and banks, called transmission losses. Transmission losses are important because water infiltrates when flood waves move through the normally dry stream channels, reducing runoff volumes and flood peaks, and affecting components of the hydrologic cycle, such as soil moisture and ground water recharge. The importance of recharge through the Walnut Gulch Experimental Watershed ephemeral stream channels has been confirmed by ground water mounding (increases in water levels in wells in and adjacent to the main channels) after flood events. Owing to the small diameter of the runoff producing storms, most flows traverse dry channels and large reductions in runoff occur. The entire watershed is highly dissected by a dense channel network providing significant opportunity for transmission losses.



An example of transmission losses is presented. The August 27, 1982 storm, was isolated in subwatershed 6 on the upper 95 km² of the watershed (and not all of that produced runoff). The runoff measured at Flume 6 amounted to $2.46 \times 10^5 \text{ m}^3$ with a peak discharge of $107 \text{ m}^3 \text{ s}^{-1}$. Runoff traversing 4.2 km of dry streambed between Flume 6 and Flume 2 resulted in significant infiltration losses. For example, in the 4.2 km reach the peak discharge was reduced to $72 \text{ m}^3 \text{ s}^{-1}$ and 48,870 m³ of water were absorbed in the channel alluvium. During the course of the 6.66 km from Flume 2 to Flume 1, the peak discharge was further reduced, and 41,930 m³ of runoff was infiltrated in the channel alluvium.



Erosion and Sedimentation

Erosion and sediment transport are highly variable across the Walnut Gulch Experimental Watershed, largely in response to variability in precipitation and runoff. The processes of erosion, sediment transport, and deposition on uplands and in ephemeral stream channels are being studied at several locations on the Walnut Gulch Experimental Watershed across a range of spatial scales.

At the plot scale, rainfall simulator experiments are being conducted to quantify the relationships between, rainfall, runoff, and sediment yield. Experiments are being designed to use rare earth elements as tracers to quantify the spatial variability of erosion at the plot scale. At the small watershed scale, sediment data are collected as part of the long-term monitoring program. Traversing slot sediment samplers located at the outlet of Santa Rita critical depth runoff measuring flumes collect sediment samples. The traversing slot sampler was designed to measure sediment concentrations under high velocity, sediment laden flow conditions. Currently, sediment concentration samples are collected at 5 small watersheds. Recently, the sampling program has been extended to quantify the transport of coarse sediment. Pit traps have been installed at 2 locations, and the displacement of individual particles is being monitored in 3 channels within the Lucky Hills Watersheds. Sediment yield is monitored at stock ponds located at the outlets of 10 small watersheds. These data are used to quantify long-term sediment yield rates and provide data critical to developing sediment budgets for semi-arid rangeland watersheds.

Collected field data and the Walnut Gulch Experimental Watershed sediment-monitoring network provide critical data for developing simulation models and rangeland assessment methods. These data have been used to develop equations to predict hydraulic geometry and erosion rates in small channels as functions of discharge, shear stress distribution, and soil properties. Collected data have been used in conjunction with current erosion prediction technologies, such as CREAMS, WEPP, and RUSLE, to improve the scientific understanding of small watershed erosion processes.



Plot scale rainfall simulator sediment yield experiment.



Traversing slot sediment sampler collects sediment samples during a flow event.

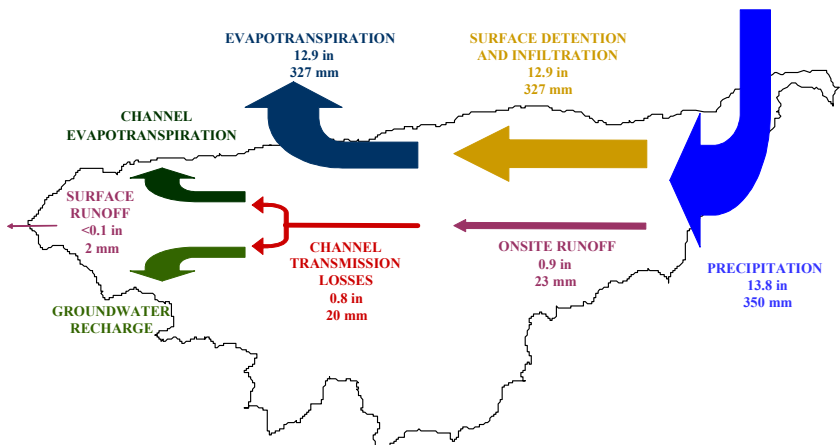


Sediment yield is monitored at stock ponds located at the outlets of 10 small watersheds.

Water Balance

The Walnut Gulch Experimental Watershed water balance, although variable from year to year as well as across the area, is obviously controlled by precipitation. The annual water balance is illustrated for average conditions. Given the average 350 mm input precipitation, approximately 327 mm is detained on the surface for subsequent infiltration. Essentially all of the infiltrated moisture is either evaporated or transpired by vegetation back to the atmosphere. Based on data collected from small watersheds, less than 1.5 hectare, approximately 23 mm of the incoming precipitation is in excess of that which is intercepted and/or infiltrates. We refer to this as "onsite runoff." As the runoff moves over the land surface and into dry alluvial channels, transmission losses begin. Approximately 20 mm of transmission losses occur and about 2 mm of surface runoff is measured at the watershed outlet. The 20 mm of transmission losses result in some ground water recharge and some evaporation and transpiration from vegetation along the stream channels. Quantities for ground water recharge and evaporation and transpiration of channel losses are not shown because their quantification is difficult and very site specific. This is an area of active research. The geology along and beneath the stream channels create some reaches that are underlain by impervious material, whereas in other locations, the channels extend to regional ground water and permit appreciable recharge. Where the channels are underlain by impermeable material, riparian aquifers connected to the channels support phreatophytes and saturated alluvium following major runoff. Potential evaporation (Class A USWB pan) is approximately 260 cm per year which is approximately 7.5 times the annual precipitation.

WALNUT GULCH EXPERIMENTAL WATERSHED ANNUAL WATER BALANCE



Instrumentation

The initial rainfall and runoff instrumentation on Walnut Gulch Experimental Watershed was installed in 1954-55. The initial network of 20 precipitation recording gauges was expanded in the early 1960's to the 88 gauge network currently in place on the watershed. Five supercritical precalibrated flumes were constructed prior to 1955 to measure runoff from the heavily sediment laden ephemeral streams. All five flumes failed or were badly damaged within two years. They failed for hydrologic, hydraulic, and structural reasons. Following extensive hydraulic model research at the Agricultural Research Service (ARS) Outdoor Hydraulic Structures Laboratory in Stillwater, Oklahoma, the original five flumes were rebuilt using a design known as the Walnut Gulch Supercritical flume. Six additional flumes were added later.

Hydro-meteorologic and soil erosion/sedimentation data are collected from 125 instrumented installations on WGEW. Precipitation is measured with a network of 88 weighing-type recording raingauges arranged in a grid throughout the watershed. Various runoff measuring structures are used to monitor small watershed (< 40 ha) runoff. These structures include broad-crested V-notch weirs, H-flumes, and Santa Rita supercritical flow flumes. Currently there are 8 small watersheds being monitored. Runoff from watersheds greater than 40 ha is measured using either livestock watering ponds or large supercritical flow flumes. The largest flume, at the outlet of the Walnut Gulch Experimental Watershed has a flow capacity of 650 cubic meters/sec. There are 10 stock pond watersheds and 11 large flume watersheds currently being monitored. Sediment from the small watersheds monitored with V-notch weirs or H-flumes is sampled with automatic pump samplers. Sediment from watersheds equipped with the Santa Rita supercritical flow flumes is sampled with a total-load automatic traversing slot sampler. Meteorological, soil moisture and temperature and energy flux measurements are made at two vegetation/soil complexes. Permanent vegetation plots and transects have been established to evaluate the impacts of management practices and global change on vegetation.

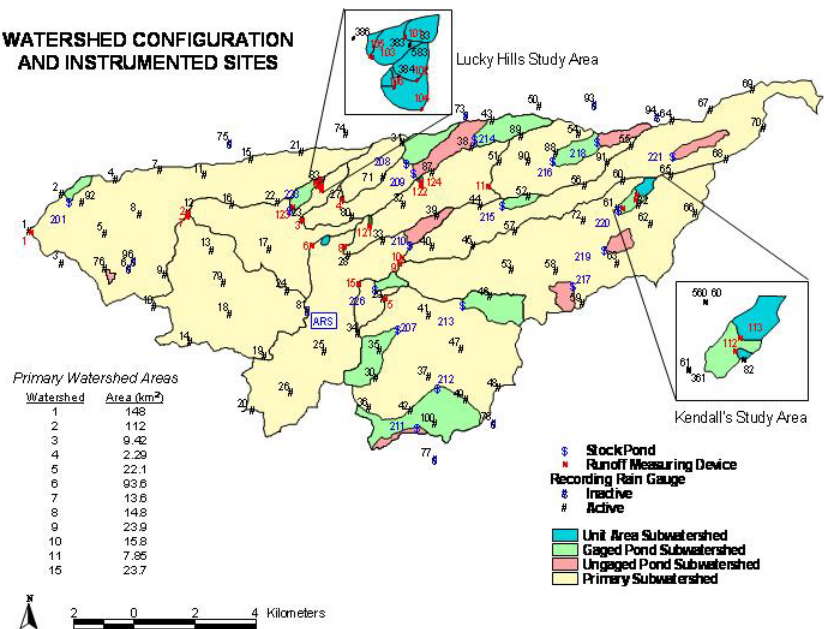
Because of the growing obsolescence of existing rainfall and runoff mechanical sensors with analog data-recording, impending reduction in staff and the labor intensive requirements to collect and process the charts, SWRC began a multi-year effort in 1996 to fully reinstrument Walnut Gulch Experimental Watershed with electronic sensors and digital data-logging capability combined with radio telemetry to allow remote data transmission and monitoring. This reinstrumentation greatly enhances our research and cooperative capabilities as well as maintaining the viability of hydrologic data collection and long term continuous record.

A high resolution, self contained, simple raingauge was designed by SWRC field technicians that has been laboratory and field tested under simulated and natural rainfall. The gauge consists of a precision, temperature compensated load cell, which measures the weight of a platform-mounted container that collects water during a precipitation event. As water accumulates in the container, the voltage output from the load cell changes. The programmed datalogger samples voltage every second and averages at 1 minute interval. To minimize data storage requirements and transmission time, only time stamps and voltages commensurate with precipitation detectable to 0.25mm precision are recorded. The capacity of the raingauge is 200mm (8 in) before it must be serviced. A very unique feature of the raingauge design is that all electronics, data logger, and radio/modem components are housed in a metal below-ground cylinder, thus reducing vandalism, lightning interference, and temperature effects.

The conversion from analog to digital output of the runoff measuring instruments

was done by attaching a precision linear potentiometer to the output gear shaft of the currently used water-level recorders. The voltage output from the potentiometer is collected by a data logger which averages 1-second samples at 1-minute intervals and records flow data (time stamp and voltage) only when a minimum depth threshold has been exceeded (0.003m at small flumes, 0.015m at large flumes and stock tanks). At sites where automatic sediment sampling is done, the data logger controls the operation of the sampler and records each sample's begin time and total time to collect the sample. Samples are collected when flow depth is greater than 0.06m.

On a daily basis, all locations are automatically and sequentially queried and data are transmitted to a dedicated computer at the Tombstone field office. Data are archived, used to generate daily reports and written to the Tucson SWRC network server using a 56K phone line. Daily data radio transmission time and size can range from a minimum of 1.5 hour and 300 KB for non-event days to over 4 hours and 1MB for a day with rainfall/runoff.





Recording Weighing Bucket Raingauge



"Santa Rita" flume with traversing slot sediment sampler



Walnut Gulch Supercritical flow flume



Meteorological station

CURRENT SWRC RESEARCH

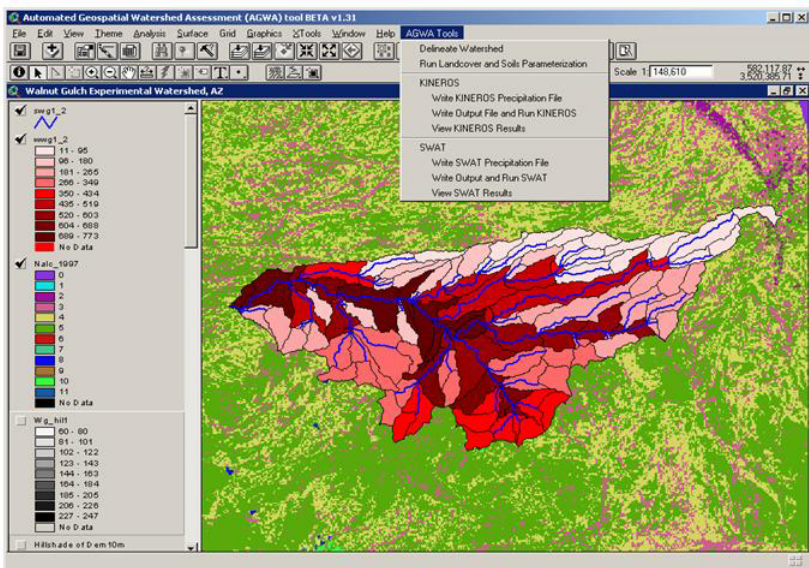
SWRC will continue to study the science and advance the knowledge of watershed hydrology to fulfill the missions of the Center and Agency making valuable use of our “outdoor laboratory”. Hereafter is a sample of some of the research projects that are being pursued on Walnut Gulch Experimental Watershed.

HYDROLOGIC PROCESSES

Automated Geospatial Watershed Assessment Tool (AGWA)

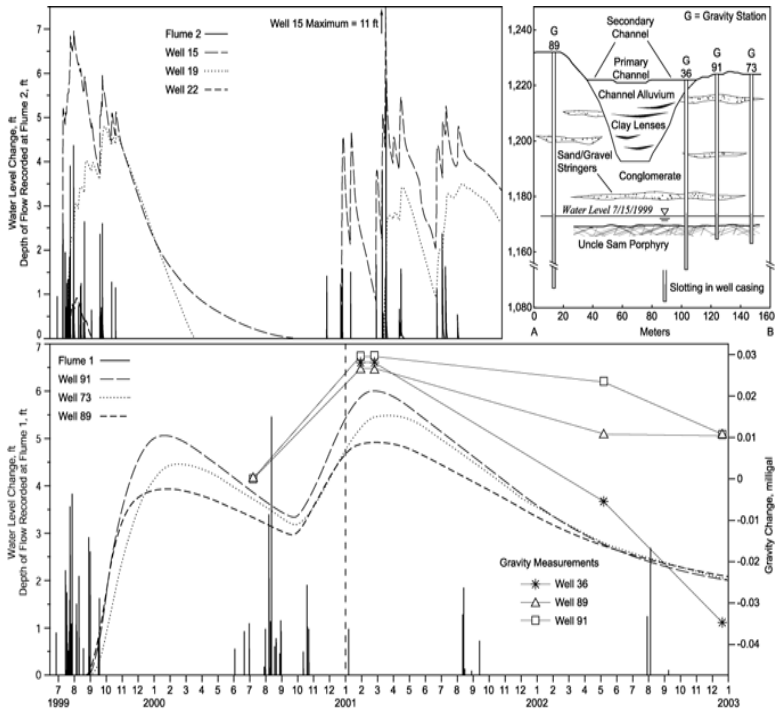
AGWA is a PC-based Geographic Information System (GIS) tool for watershed modeling. Embedded in AGWA are two sophisticated hydrologic models, SWAT and KINEROS – both of which were developed by ARS and the latter by scientists at SWRC, which operate over two distinct spatial-temporal scales. AGWA is used by scientists and natural resource managers to investigate the impacts of land cover change on runoff, erosion, and water quality. Ground based hydrologic data from Walnut Gulch Experimental Watershed were used to calibrate and validate AGWA.

AGWA ArcView Interface



Ephemeral Channel Recharge

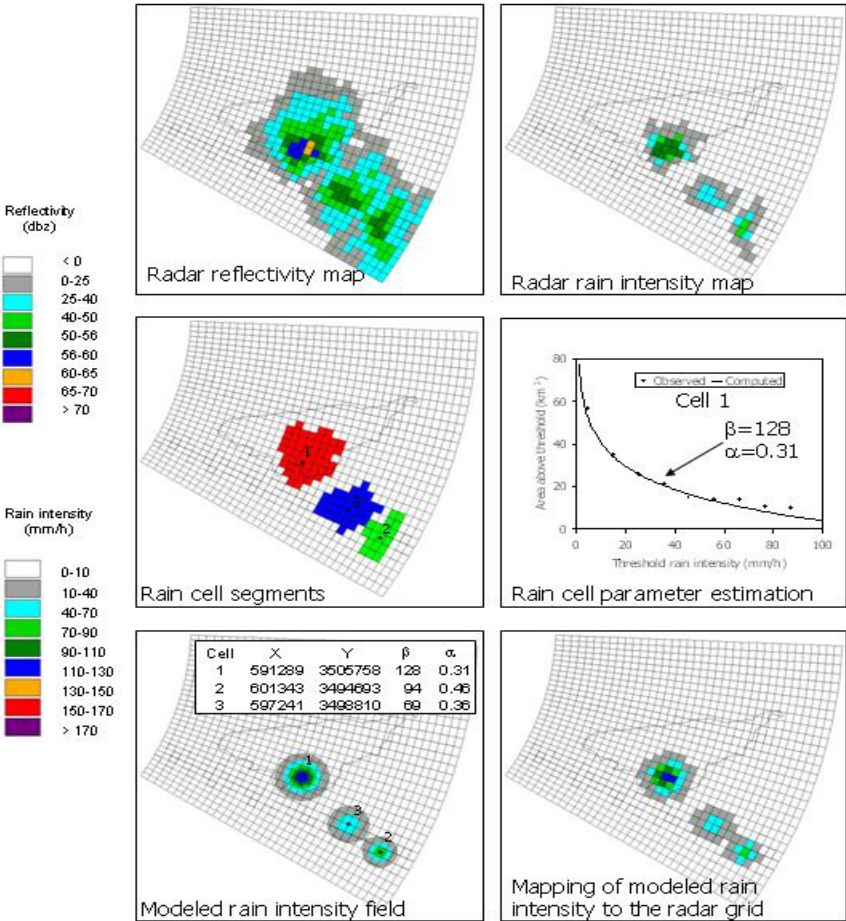
Ephemeral channel transmission losses play an important role in ground water/surface water dynamics in arid and semi-arid basins in the Southwest. However, identification of the processes driving these dynamics is difficult. Quantifying recharge with greater certainty is a critical need required to manage basins whose primary source of water supply is derived from groundwater. This issue was addressed via coordinated field research within the Walnut Gulch Experimental Watershed. Groundwater, surface water, chemical, isotopic, tree sap flux, micrometeorological techniques, and changes in microgravity were used to independently estimate ephemeral channel recharge. Wet 1999 and 2000 monsoon seasons caused substantial changes in near-channel groundwater levels. Results indicate relatively good agreement between the average estimates from each of the methods, in that they differ by less than a factor of three. This range is not surprising given the limitations of the various methods, and the differences in time scales over which they are applicable. Crudely scaled to the basin level, this recharge would constitute between 20 and 50% of basin recharge as estimated from a calibrated groundwater model.



Well levels and flow depths at flume 2 (top) and flume 1 (bottom). Bottom figure also shows gravity measurements at flume 1. Diagram on upper right shows cross section of well transect above flume 1.

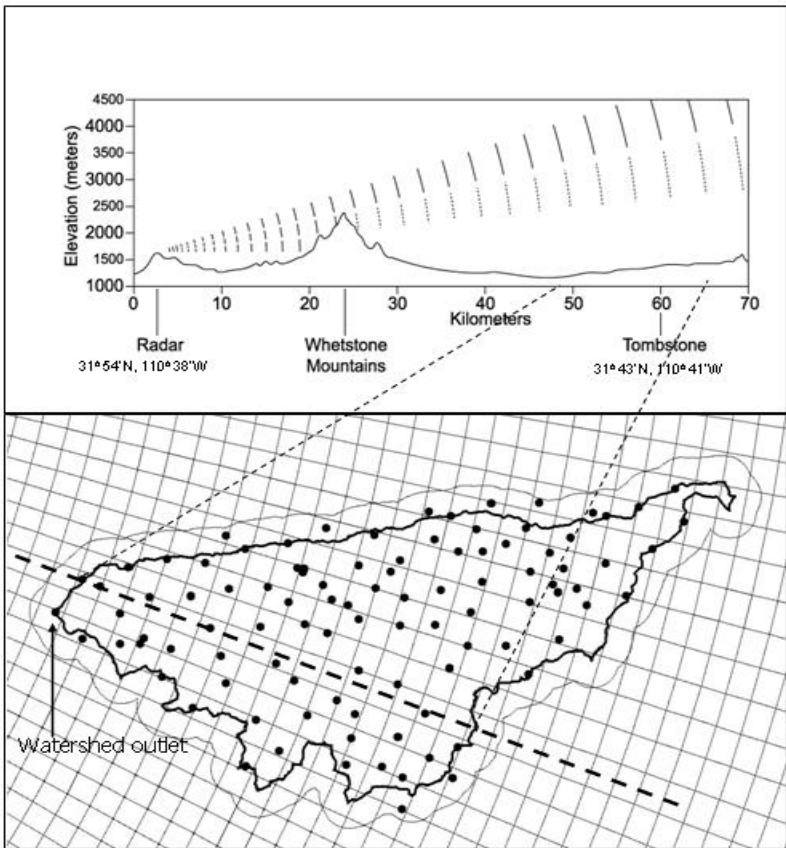
Modeling Rainfall Spatial Patterns and Linkage to Hydrologic Runoff Model

Rain systems possess characteristic structures of spatial patterns that evolve from underlying processes in the systems. The important role of these rainfall patterns in watershed hydrology has been long recognized. This research is developing a conceptual model of rainfall spatial patterns associated with air mass thunderstorm events using observed radar data. The rain model was applied to radar rainfall data in Arizona and evaluated using rainfall data from Walnut Gulch Experimental Watershed. The use of the modeled rainfall as input to a distributed hydrological model will be demonstrated. Using this approach allows comprehensively linking runoff response and spatial rainfall patterns. Through conceptual rainfall modeling, new insights can be acquired in understanding the behavior of the rain and hydrological systems and their interaction.



Evaluating NEXRAD Radar-Rainfall Relationship

NEXRAD is a remote sensing system, developed and operated by the National Weather Service, that provides rainfall estimations at high spatial and temporal resolution. The radar-based rainfall intensities are calculated from the observed radar reflectivities. Rain gauge rainfall observations are used in combination with the radar data to find the optimal relationship. Radar and gauge data were analyzed from 15 convective storms in 1999 and 2000 over Walnut Gulch Experimental Watershed. Identification of the optimal relationship requires further knowledge on reflectivity and the rain intensity error structure.

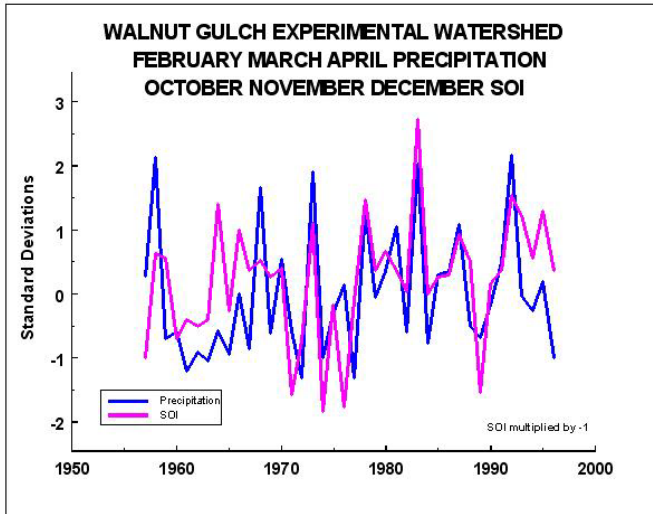


Linking the El Nino Influence to the ARS Stochastic Weather Generator

Computer models called stochastic weather generators simulate daily weather values such as precipitation and temperature. These simulations of daily weather are necessary for agricultural and natural resource management and planning as well as for a variety of economic and commercial situations such as construction, transportation and recreation scheduling. The Walnut Gulch Experimental Watershed historical precipitation record is being used to make improvements to the ARS stochastic weather generator by incorporating global scale influences.

Regional precipitation in the western US is differentially influenced by the El Nino-Southern Oscillation (ENSO) phenomenon. The Southwestern US receives greater than normal winter precipitation under warm episode ENSO (El Nino) conditions. The opposite is true for precipitation when cool ENSO (La Nina) conditions prevail. ENSO is an ocean-atmospheric phenomenon which can be enumerated by the monthly Southern Oscillation Index (SOI), which represents the deviations of observed atmospheric pressure from long-term averages in the equatorial Pacific.

It has been shown that there is a significant influence of the SOI on daily precipitation for Tombstone which is also true for the Southwest US. The lead-time between ENSO conditions and western US weather is 3 to 4 months, e.g. October through December SOI significantly impacts February through April precipitation. Current research is directed at identifying ENSO effects on temperature and other weather variables and examining other large-scale influences such as sea surface temperature.



EROSION and SEDIMENTATION

Tracking Coarse Particle Movement with an R.F.I.D. System

Vast areas of rangeland in the semi-arid southwestern US are characterized by ephemeral channels that transport sediment during occasional flows. Sediment, ranging in size from silts and clays to large gravels and cobbles, is transported during channel runoff associated with intense summer thunderstorms. Thunderstorm generated runoff hydrographs are characterized by short durations and large peak flows. Runoff and sediment data are collected at the outlet of upland watersheds on the Walnut Gulch Experimental Watershed. Within the Lucky Hills Watersheds, critical depth runoff-measuring flumes and depth-integrated traversing slot samplers collect runoff and sediment during flow events. Although the traversing slot collects a depth-integrated sample, computed concentration values do not represent sediment particles greater than the 13 mm slot width.

Recently, an experiment was undertaken to track the movement of individual coarse particles using radio frequency identification (R.F.I.D.) tags. During the 2002 and 2003 runoff seasons, 200 tagged particles were placed in 3 channels in the Lucky Hills Watersheds. Particles were located, and their position was measured, after each flow event. The tracking system consists of transponders, an antenna, a reader, and computer software. The position of each particle was measured using a differential GPS system.

The R.F.I.D. system offers the advantages of low cost, consistent results under harsh environmental conditions, and no need for a power supply in the particle. The R.F.I.D. system offers the potential to efficiently collect data for developing sediment transport equations and improving mathematical models for simulating sediment transport under natural runoff conditions.



Field Experiments – Particle Tracking



Walnut Gulch Rainfall Simulator

The Walnut Gulch Rainfall Simulator (WGRS) is a portable, computer controlled, variable intensity rainfall simulator. The WGRS was developed to be used in field studies to quantify the relationship between rainfall intensity and steady state infiltration rate and to determine how that relationship affects sediment transport by overland flow. The simulator has a single central oscillating boom and applies water over a 2m by 6.1m area. A computer controlled stepper motor is used to minimize the variability of the water application across the plot. The spray time and sequence of nozzle operation are controlled by 3-way solenoids to minimize the delay time between oscillations at low application rates. The simulator applies rainfall rates between 13- and 178 mm/hr, in 13 mm/h increments, with a coefficient of variability of 11 percent or less across the plot. Water use is minimized by “recycling” the water that is not sprayed directly on the plot back into a water tank adjacent to the simulator. The simulator has been tested in both laboratory and field applications. The runoff and erosion generated from the WGRS are shown to be comparable with those generated using the rotating boom simulator.

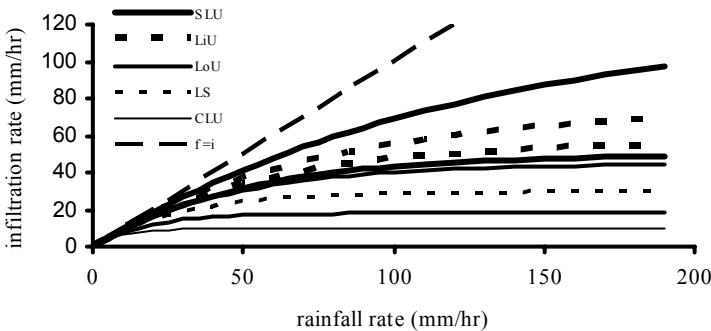
The WGRS is being used to measure infiltration, runoff and erosion processes on a selection of ecological sites within southeastern Arizona. Using the WGRS, runoff and erosion responses are measured for a large range of rainfall intensities. Runoff depth is measured at the down slope outlet of a 2 m by 6 m plot using a pressure transducer attached to a pre-calibrated flume. Runoff depth is converted to discharge using the flume’s stage-discharge relationship. Plot average steady-state infiltration rates as a function of rainfall intensity are calculated by subtracting the measured steady-state runoff rate from the applied rainfall rate. Erosion rates as a function of rainfall intensity are measured using “grab” sediment samples taken at the flume outlet. The samples are dried and weighed to compute sediment concentrations. In addition, plot characteristics, vegetative canopy cover and surface ground cover, are measured using the point intercept method at 400 points on each plot. The ability to apply a large range in rainfall intensities under controlled conditions has increased and enhanced the knowledge and insights into hydrologic and erosion processes gained from rangeland plot studies.



The Walnut Gulch Rainfall Simulator setup for a field experiment.

Rainfall Simulator Runoff and Erosion Experiments

Soil-vegetation associations are classified into ecological sites and used for rangeland evaluation and planning. How the amounts and rates of runoff and erosion from an ecological site change in relation to changes in ecological condition has not been well quantified. In addition, indicators of hydrologic and erosion potential are being developed for rangeland monitoring and assessment and are in need of validation. Data from rainfall simulator experiments conducted at the Walnut Gulch Experimental Watershed and in northern Chihuahua, Mexico, show that runoff response is more variable within an ecological site than among ecological sites and that there is probably a continuum of hydrologic response among ecological sites with similar soil types. The results also show that there is a strong relationship between steady state infiltration rate and rainfall intensity with the infiltration rate increasing with increasing rainfall rate, illustrated below. This relationship is more significant for coarse textured soils, which are typical of many rangeland sites. The implication of this result is that at low to moderate rainfall intensities, runoff only occurs on parts of the area (partial area response). Although there is a significant correlation between runoff response and the percentage of bare soil, the data suggest that determining how bare areas are connected to each other may be important in predicting how an ecological site will respond hydrologically. In contrast to the hydrologic response, the erosion response appears to be more indicative of ecological condition. In other words, ecological sites that are in poor condition have significantly more erosion than those in good condition. Partial area response also affects sediment yield in that runoff flowing only on a portion of the area does not have enough energy to transport all of the sediment that is detached by raindrop impact. At higher rainfall intensities, the flow covers the entire area and the amount of erosion increases dramatically. Currently, experiments are being conducted using the Walnut Gulch Rainfall Simulator in southeastern Arizona on ecological sites with a broad range of soil textures and ecological conditions. The experimental design includes applying rainfall intensities varying from 13 to 178 mm/hr in order to quantify the relationship between infiltration and rainfall intensity and to evaluate the effects of partial area response on sediment yield.



Relationship between infiltration rate and rainfall rate for five ecological sites: Sandy Loam Upland (SLU), Limey Upland (LiU), Loamy Upland (LoU), Limey Slopes (LS), and Clay Loam Upland (CLU). With the exception of LS, which has desert shrubs as the dominant vegetation, all of the ecological sites are desert grasslands.

Hillslope Erosion and Landscape Evolution on Semi-arid Rangelands

Data on hillslope erosion rates in semi-arid rangelands is scarce. The Walnut Gulch Experimental Watershed provides an outdoor laboratory for evaluating and measuring erosion rates with different soils and vegetation regimes. Such data are used for developing and improving soil erosion models, which are used as tools for evaluating land management practice effects on erosion, and for implementing national soil conservation programs. Current work at Walnut Gulch Experimental Watershed involves using new and innovative techniques for measuring the spatial distributions and rates of erosion on hillslopes. These techniques include the use of special chemicals, rare earth elements, as tracers. These tracers are completely benign and require only miniscule application rates to be effective. They bond very well with fine soil material on the hillslopes, and thus make excellent sediment tracers. Other techniques to be used include short range photogrammetry and long-term erosion bridge measurements. One of the projects associated with this work will be a large-scale outdoor experiment on landscape evolution, where we will look at the processes associated with development of gullies and how cutting of gullies into the landscape affect hillslope erosion rates. This work relies also on the measurements of sediment leaving the small watersheds (Lucky Hills and Kendall), which have been measured for many years and will continue to function in the future.



Hillslope erosion observable from exposed root length

GLOBAL CHANGE and CO₂ FLUXES

Plant Water Use Efficiency

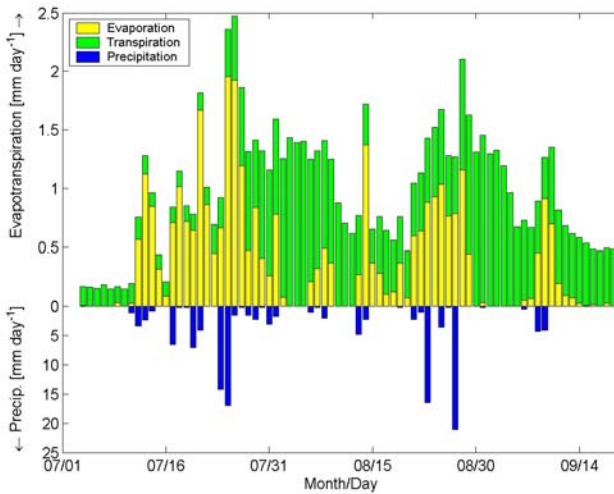
Information on the relationships between plant material production and the amount of water used to produce the material is necessary to our understanding of how different plant vegetation type communities function. Water use efficiency (WUE) can be defined as the ratio of plant material produced to the amount of water used to produce the plant material. The plant community that produces more plant material with the same amount of water is a more water use efficient community. In the arid rangeland areas of the western U.S., shrublands and grasslands are two of the major plant communities. Shrublands have been increasing in area with the loss of grasslands. Information on the WUE of these two plant communities could help explain why this is happening. Research on the Walnut Gulch Experimental Watershed in a shrubland and grassland plant community is investigating the production of plant material and the use of water in these communities. Bowen ratio systems, technology that has not been available until recently, are being used to measure the movement of carbon as carbon dioxide into the communities and water out as water vapor. The uptake of carbon dioxide by the plants during photosynthesis to produce plant material is used as a measure of plant material production. The measurement of water vapor leaving the plant communities represents both water loss from evaporation from the soil surface and from water leaving the plants during photosynthesis. The results of the measurements are indicating the grassland plant community is producing more plant material with the use of less water making it more water use efficient under the present atmospheric concentration of carbon dioxide. The grass plants have a more efficient photosynthetic pathway to convert carbon dioxide into plant material than the shrub plants. This could explain some the higher WUE of the grass plant community. As we all know the carbon dioxide concentration is increasing in the atmosphere. Research has shown that the shrub plants become more efficient at converting carbon dioxide into plant material as the concentration of carbon dioxide increases. This increasing WUE of the shrub plants may explain why shrublands are increasing in aerial extent. Additional research will be conducted on Walnut Gulch Experimental Watershed to further our understanding of these two important plant communities in rangeland ecosystems.



Bowen ratio system at the Walnut Gulch Experimental Watershed grassland study site used to measure carbon dioxide and water vapor movement.

Partitioning Precipitation to Evaporation and Transpiration

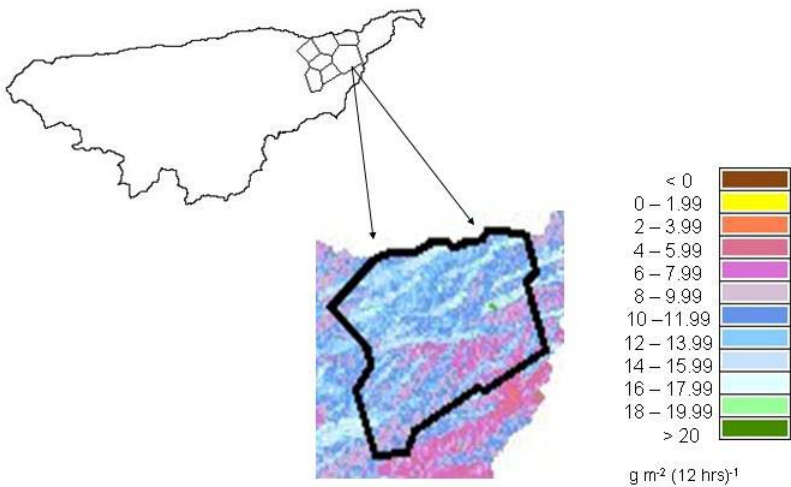
Using a combination of Bowen ratio and sap flow techniques, on-going research is quantifying the amount of precipitation that is lost to evapotranspiration and how this loss is partitioned into evaporation from the soil and transpiration from the plants. Below, preliminary data collected during the 2003 monsoon at the shrub-dominated Lucky Hills Site in the Walnut Gulch Experimental Watershed shows how precipitation excess was partitioned into evaporation and transpiration. At the onset of the summer rains, most of the evapotranspiration was dominated by bare-soil evaporation as it took a couple of weeks for the shrubs to become active. After shrub green-up, evapotranspiration was dominated mainly by transpiration in the interstorm periods whereas bare-soil evaporation diminished rapidly following rain events as the surface soil layer quickly dried up.



Eddy covariance, Bowen ratio and sap flow sensors at Lucky Hills.

Mapping Regional Estimates of Grassland CO₂ Flux

Semi-arid grasslands comprise a large portion of the world's rangeland ecosystem and may play a significant role in the carbon cycle. Grassland CO₂ fluxes are being measured in various places around the world as part of the ongoing effort to understand the global carbon budget. The Walnut Gulch Experimental Watershed contains instrumentation to monitor CO₂ flux over areas covering a few hundred meters. Historical data available from this instrumentation made it possible to combine remotely sensed surface reflectance and temperature measurements with meteorological data to estimate the distribution of CO₂ flux over several square kilometers. Thus, satellite images can be used to provide regional estimates of CO₂ flux. The use of these CO₂ maps will help to provide a better picture of both the current role and possible future role semi-arid grasslands play in understanding the global carbon budget.

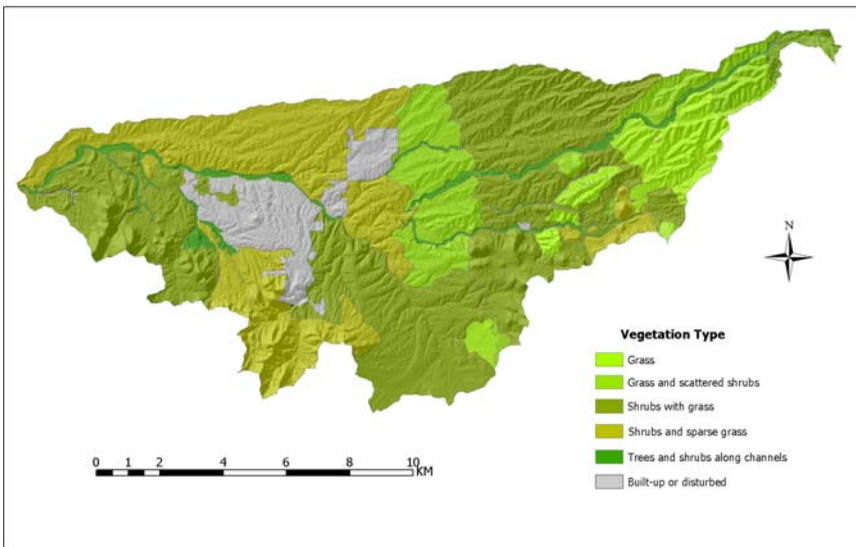


Grassland CO₂ flux map derived from Landsat TM imagery for 9/26/99

REMOTE SENSING

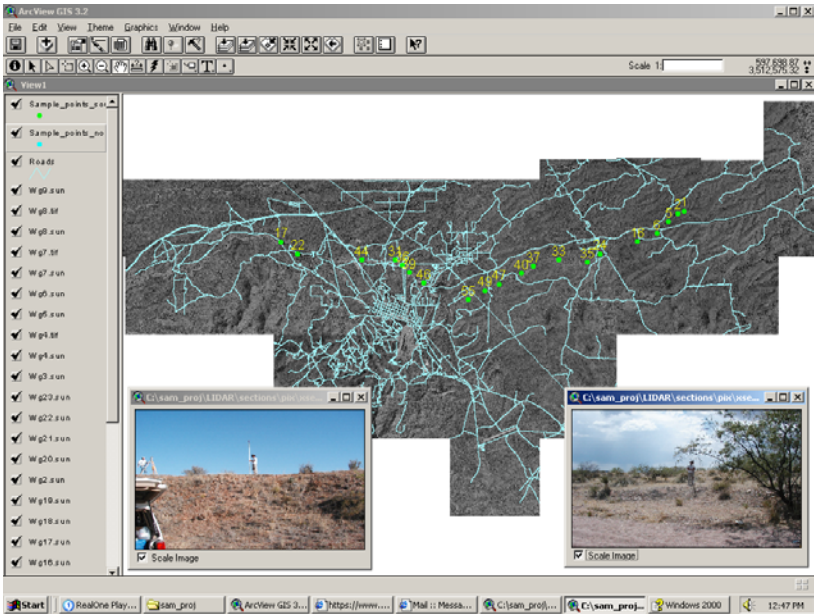
Vegetation Mapping

In collaboration with the US Army Topographic Engineering Center, researchers at SWRC are validating a vegetation map that will be used with remote sensing and other data for modeling of biophysical properties of the watershed. The map was made using photo interpretation of aerial photography and other remotely sensed data. Field validation is important to quantify the map's accuracy and uncertainty, and to locate problem areas. When the validation work is complete, the map will provide information about the kind, location, and amount of different vegetation types in the Walnut Gulch Experimental Watershed. This information will also help in understanding other kinds of data such as satellite images, soil moisture and carbon dioxide flux measurements, the effects of land management practices, and changes in vegetation over time including the ongoing encroachment of woody plants into grassland areas.



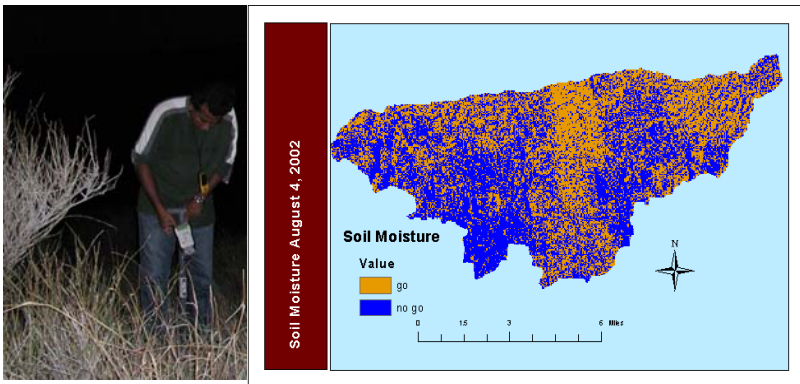
LIDAR Measurements

Accurate representation of watershed topography and above ground vegetation structure are critical to adequately model and predict watershed storm response, erosion, sediment transport and vegetation transpiration. The current consensus in the hydrologic research community is that fundamental advances in watershed modeling and prediction are limited by our field characterization abilities and not by our modeling and computational capabilities. We are in the process of analyzing and studying the capability of airborne ALSM (Laser Imaging Data And Ranging) to provide accurate, high-resolution delineation of watershed topographic characteristics (slope, roughness, channel geometry, drainage area, etc.) and the ability to incorporate this information readily into distributed hydrologic runoff, erosion, and sediment transport models. Because ALSM obtains a primary (ground) and secondary (above ground vegetation, structures, etc.) range return, we hypothesize that ALSM analysis can be developed to provide measures of above ground vegetation and characteristics of its structure. Prior research in riparian systems has demonstrated that the size and canopy structure of cottonwood trees significantly affects their total transpiration water use. However, multi-spectral remotely sensed imagery alone cannot distinguish between younger, cylindrical cottonwoods, with a higher leaf area index, and older, crown shaped cottonwoods. An initial ALSM remote sensing mission (LIDAR) mission was carried out in June 2003 over the heavily instrumented Walnut Gulch Experimental Watershed and the San Pedro National Riparian Conservation Area riparian corridor with coordinated ground measurements of both surface topography and above ground vegetation characteristics. A second, post-monsoon mission is slated for Oct. 2003.



Remote Sensing of Soil Moisture for Battlefield Applications

The U.S. Army needs accurate and timely soil moisture information to plan troop movements and estimate mobility over large areas. Historically, vehicle movement has been hampered by wet soils causing disruption and danger when vehicles got stuck. Existing radar satellites may be capable of estimating soil moisture content over large areas and have several advantages over other techniques. These include the ability to 'see through' clouds, and the ability to operate at night, in addition to covering vast areas at relatively high resolution. The USDA-ARS in conjunction with NASA, and the U.S. Army Topographic Engineering Center is conducting research to determine the feasibility of radar remote sensing for Army applications. One aspect of the research effort involves ground-truthing soil moisture content at the time of satellite overpass. Another approach uses a physics based computer model to compute soil water content based on the received satellite signal. After soil moisture content is determined over large areas, it will be modeled forward in time using sophisticated models that can predict soil moisture between satellite overpass dates.

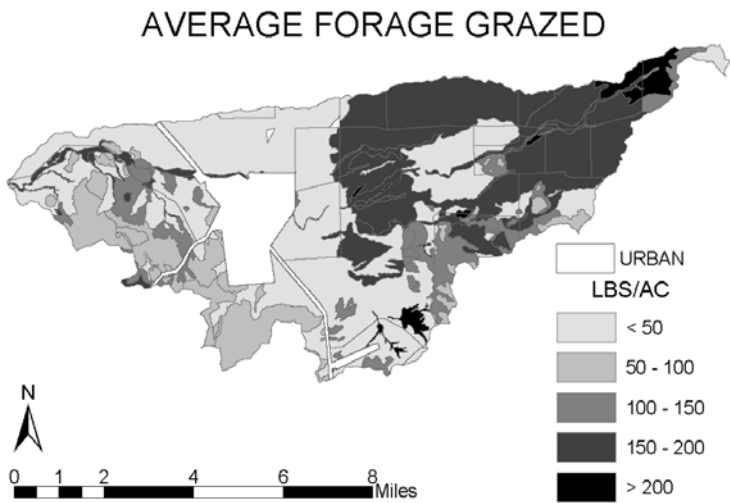


Field verification of soil moisture at time of satellite overpass, and preliminary soil moisture map developed by comparing a radar image acquired during the dry season with one acquired a few hours after a monsoon storm.

DECISION SUPPORT SYSTEMS

Economic analysis of rangeland management

Implementation of soil and water conservation measures is often limited by the ability of such measures to justify the investment. Economic analysis of rangeland management practices on Walnut Gulch Experimental Watershed has been a long-term goal, but had been limited in the past. With the University of Arizona, there is a project to develop a Spatial Decision Support System to support the development of erosion control plans on rangelands. Part of the project is an effort to calculate the costs of reducing erosion from uplands. The Walnut Gulch Experimental Watershed is treated as if it were a single ranch. The approach uses an optimization model to mimic a rancher selecting the stocking rate and other management practices for each pasture to maximize the rancher's net returns subject to constraints on the amount of erosion on the watershed. A higher stocking rate implies more income but less vegetative cover and so more erosion. As shown in the image, forage grazed and other variables are calculated for each ecological site within each pasture across the watershed and can be displayed as maps. Research is ongoing, but preliminary results indicate that the short-term potential to reduce erosion through vegetation management is limited.



CURRENT COLLABORATIVE RESEARCH

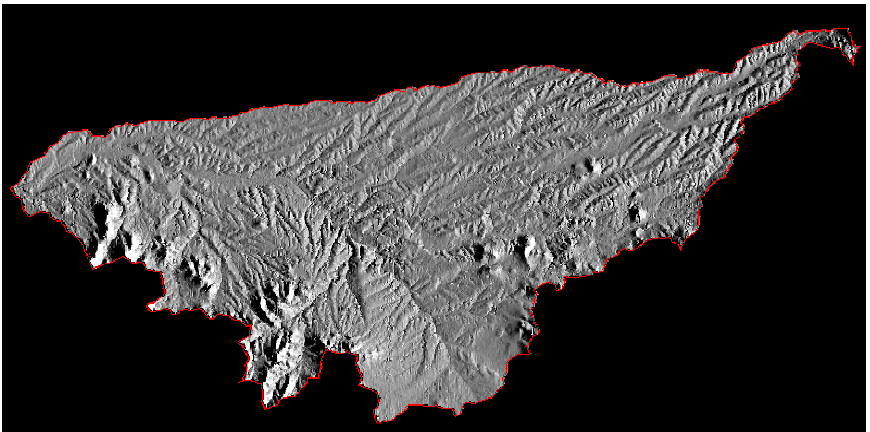
Interdisciplinary research projects are the hallmark of the Walnut Gulch Experimental Watershed attracting a variety of researchers because of the documented record of experimentation, data collection, excellent infrastructure and SWRC support. SWRC has a long history of cooperative work with many foreign countries, national and international organizations, universities and local, state and federal governments. Many of these projects are related to other initiatives, at the regional, national or global scale to extend the watershed knowledge gained at Walnut Gulch Experimental Watershed to a broader audience of scientists, decision-makers, and the public.

- The ARS Hydrology Laboratory, Beltsville MD is collaborating with SWRC scientists using ^{137}Cs tracer to delineate and quantify spatial distributions of soil erosion in two small watersheds at Walnut Gulch.
- Walnut Gulch Experimental Watershed carbon flux research sites are part of the USDA-ARS AgriFlux project. The focus of this collaborative project is to evaluate the potential of rangelands and croplands to sequester carbon into the soil and mitigate increasing atmospheric carbon dioxide concentration.
- The Weather Simulation Team (WST) is composed of scientists from multiple ARS locations and the NRCS National Water and Climate Center. Their goal is to improve and enhance the ARS-NRCS weather generator model, Generation of weather Elements for Multiple applications (GEM).
- SWRC is participating with the ARS Hydrology Laboratory, Beltsville Maryland and NASA – Marshall Space Flight Center on ground based soil moisture measurement for validation of the Advanced Microwave Scanning Radiometer - EOS (AMSR-E) aboard the EOS Aqua satellite.
- Collaboration has been developed with scientists from USDA-ARS, US Army, NASA, and the University of Wyoming. The goal is to provide the Army with a prototype operational soil moisture modeling system based on remote sensing technology, process-based models, and geographic information systems.
- In collaboration with the Jet Propulsion Laboratory and the University of Arizona, scientists with SWRC are helping test prototype equipment, suitable for deployment on satellites, measuring sub-surface soil moisture.
- NEXRAD rainfall-radar relationship research and the associated modeling of rainfall fields are being done in conjunction with the National Weather Service, University of Arizona, and with the assistance of the United States - Israel Bi-national Agricultural Research and Development Fund.
- SWRC scientists are working with researchers at the University of Arizona and the University of Wyoming to better understand the consequences of woody plant encroachment on water, carbon and energy cycling.
- SWRC scientists are working with researchers from the Universities of Sheffield and Leicester in England on measuring channel geomorphic processes.
- SWRC scientists are working in cooperation with scientists from 6 different countries using runoff and sediment data from Walnut Gulch to evaluate the potential impact of climate change on soil erosion rates and soil conservation policy.
- SWRC is collaborating with scientists from the University of Catania, Italy and Beijing Normal University, China in a comparative study of data and models of soil erosion rates for semi-arid regions.

WALNUT GULCH EXPERIMENTAL WATERSHED (WGEW) RESEARCH ACCOMPLISHMENTS

- WGEW is the most highly instrumented semi-arid experimental watershed in the world.
- WGEW has produced a 50-year continuous record of precipitation from a high-density raingauge network of about 1 gage per sq. km over 150 sq. kms.
- The temporally continuous, spatially extensive WGEW precipitation database was used to develop the first depth-area-intensity relationships for semi-arid convective airmass thunderstorms.
- The nearly 50-year continuous record of precipitation and runoff at WGEW has been key to development and validation of many hydrology and erosion models, including the award-winning KINEROS runoff model.
- The WGEW erosion database provided significant input to the internationally acclaimed USLE/RUSLE conservation planning technology.
- WGEW is the site of the first quantification of transmission loss in ephemeral channels; the method has since been adopted internationally for hydrologic planning.
- Flume 1 at WGEW is the largest pre-calibrated structure to measure runoff in semi-arid areas in the world.
- 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 of rangeland hydrology and erosion.
- WGEW is the site of the development and first evaluation of land imprinting systems for both brush management and seedling establishment.
- WGEW research contributed to water harvesting technology used worldwide.
- WGEW has one of the largest published collections of satellite- and aircraft-based imagery with coordinated ground observations in the world.
- ARS scientists working at WGEW have been recognized with some of the highest awards for scientific excellence.
- The WGEW facilities have attracted national and international scientists to Tombstone, Arizona to study semi-arid hydrology and overland flow.
- WGEW scientists and facilities have set the stage around the world for "how to" conduct watershed hydrology studies.

Notes



Digital Elevation Model - Walnut Gulch Experimental Watershed

CONTACT INFORMATION

Field Supervisor
Walnut Gulch Experimental Watershed
PO Box 213
932 Old Bisbee Highway
Tombstone, Arizona 85638
Phone: 520-457-3321

Research Leader
Southwest Watershed Research Center
2000 East Allen Road
Tucson, AZ 85719
Phone: 520-670-6380
www.tucson.ars.ag.gov

