Vegetation data, Walnut Gulch Experimental Watershed, Arizona, United States

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[1] The U.S. Department of Agriculture Agricultural Research Service Southwest Watershed Research Center Walnut Gulch Experimental Watershed (WGEW) is an outdoor laboratory located in southeastern Arizona to study water and soil conservation in semiarid lands. Permanent vegetation transects were established adjacent to 55 rain gauges within WGEW in 1967 to quantify vegetation. Some sites were subsequently added or dropped. Detailed vegetation data were collected in 1967, 1994–2000, and 2005, including repeat photography of transects. Ground cover data were collected after 1967. A vegetation map was developed in 2002. The transect sites, vegetation map, data collection methods, and current data availability are described. Data are available at http://www.tucson.ars.ag.gov/dap/.

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1. Introduction

[2] The U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) Southwest Watershed Research Center (SWRC) Walnut Gulch Experimental Watershed (WGEW) is a 150 km^2 outdoor laboratory located in southeastern Arizona with the mission to develop knowledge and technology to conserve water and soil in semiarid lands [*Renard et al.*, 1993, 2008]. Collection of WGEW vegetation data was initiated in 1967 to complement hydrological and soils research. Permanent vegetation transects were established at rain gauges [*Goodrich et al.*, 2008] across the watershed (Figure 1). The transects were surveyed in detail and photographed at intervals from 1967 to 2005. A herbarium was established in 1967 at the WGEW ARS facility in Tombstone to document watershed species.

[3] Additional WGEW vegetation-related data have been acquired over a long period. A number of historic photographs showing vegetation date back to the earliest years of mining at Tombstone in the 1880s. A new vegetation map for WGEW was created in 2002, with validation work beginning in 2003. Biomass data collected for a variety of research projects will be archived at a future date.

[4] With the exception of conference abstracts that mentioned transect data [*Kidwell et al.*, 1998; *King*, 2005; USDA-ARS Southwest Watershed Research Center, Conference on Assessing Capabilities of Soil and Water Resources in Drylands: The Role of Information Retrieval and Dissemination Technologies, International Arid Lands Consortium, Tucson, Arizona, 20–23 October 2002, available at http://ag.arizona.edu/oals/IALC/conference/conference_proceedings.html], detailed WGEW vegetation data have not been previously described in the literature. This data set is notable for its repeated measurements and photography, spatial distribution throughout the watershed, and the concurrent availability of climate, hydrological, and soil dynamics data for the watershed. Such long-term ecological data are valuable for informing land management as well as basic research. They are especially useful for modeling and simulation of natural systems to examine complex relationships among vegetation, climate, hydrology, edaphic factors, and disturbance including human impacts.

2. Description of Vegetation Data

2.1. Transect Description and History

[5] In 1967, J. L. Gardner established and collected data at 55 sets of paired transects at selected rain gauges within WGEW "for the purpose of following any vegetation changes that may occur with time" (unpublished data, 1967). Vegetation transect sites were distributed across the watershed at elevations ranging between 1252 and 1718 m (Figure 1). A set of two transect lines were established at each site, with one exception (at rain gauge 60, or RG 60) having two sets for a total of four transects. The paired transect lines are parallel, 30.5 m (100 ft) long and 15.2 m (50 ft) apart, with each end marked by a short steel bar set into the ground and covered with a small cairn of rocks. The

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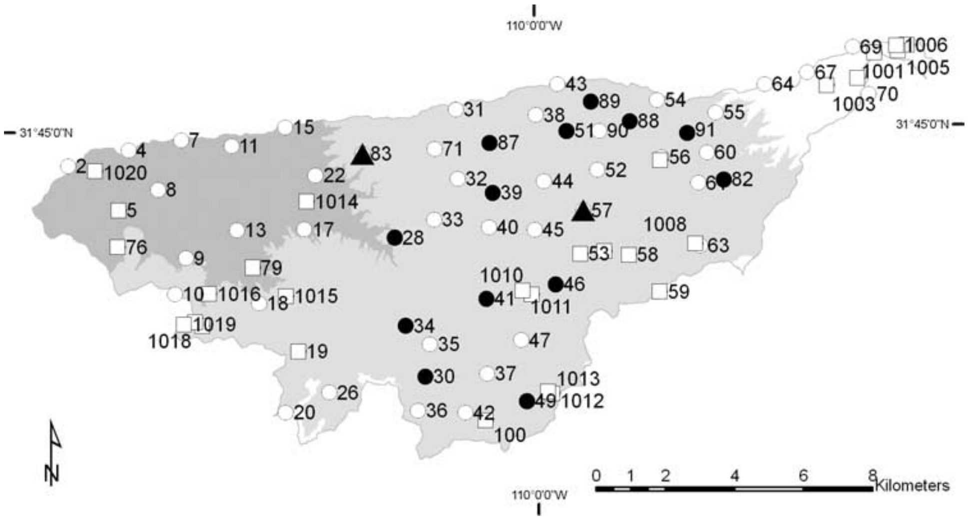

Figure 1. Spatial distribution of vegetation transect sites at WGEW, displayed on elevation data. Site numbers < 1000 are collocated with rain gauges of same number; numbers > 1000 are sites not at rain gauges. White circle, established 1967 and resurveyed 1994; dark circle, established 1967 and resurveyed 1994, 1999, and 2005; triangle, established 1994; square, established 1995. Elevation intervals: dark, 1220–1450 m; medium, 1450–1700 m; light, 1700–1950 m.

adjacent rain gauge usually marks the apex of an isosceles triangle, with the near ends of the transects defining its basal vertices. Overlapping photographs were taken of each transect line from the adjacent rain gauge, showing both foreground vegetation and the skyline in the background. All transects were photographed in 1967 and 1994, and a subset was photographed in 2005 (Figure 2).

[6] Two sites could not be resurveyed in 1994 (RG62, no stakes found; RG14, destroyed by road construction). New transects were established at RG 57 and RG 83 in 1994, following the layout described above and resulting in a continued total of 55 sites.

[7] In 1995, 28 additional sites were established to sample all USDA Natural Resource Conservation Service

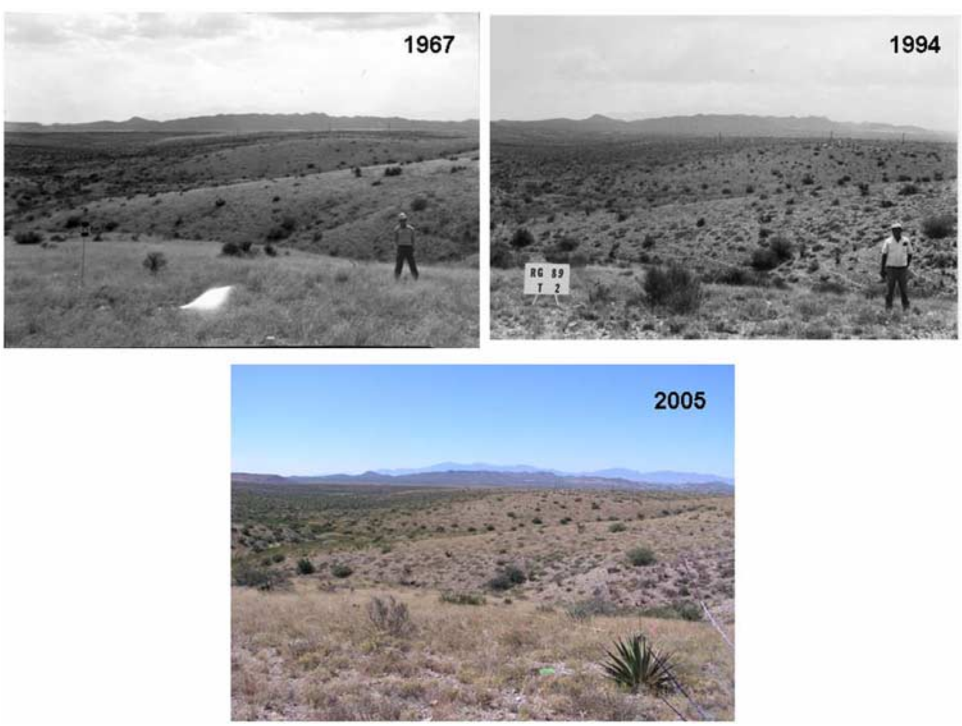

Figure 2. Historic and recent photography, west transect line at site 89 (grass dominated). Some vegetation demographics are evident in the photos: the large shrub in the left foreground in 1994 (*Ephedra trifurca* Torr. ex S. Wats.) grew to size between 1967 and 1994 and appeared dead by 2005. Some shrubs on far slopes are visible in all three photos.

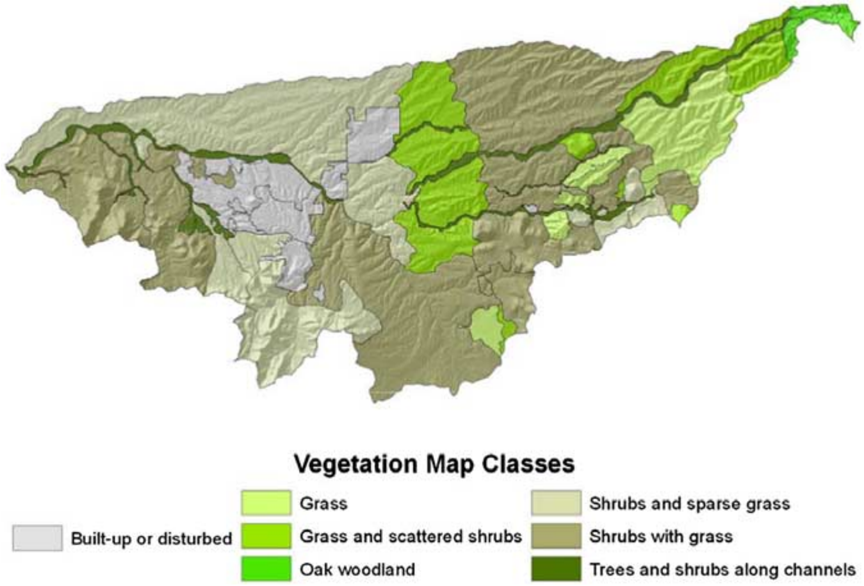

Figure 3. WGEW vegetation map displayed on shaded relief background.

(NRCS) ecological sites present at WGEW. Only 8 of these additional sites are located at rain gauges (Figure 1). GPS coordinates for the other 20 additional sites were recorded and a T post was set 15.2 m (50 ft) from the transect lines to assist in locating the sites for subsequent surveys.

2.2. Vegetation Map

[8] A new WGEW vegetation map was developed in 2002 (Figure 3). Cover type labels were assigned to polygons by dominant life forms (tree, shrub, grass) with ancillary information on substrate type (e.g., rocky outcrop, sandy loam) or location near wash (see examples in Table 1). The 74 map polygons included 10 nonvegetated polygons consisting of mines, mine spoil areas, and developed areas primarily in and near the town of Tombstone. Vegetation class names were added to reflect the primary distinction between shrub-dominated and grass-dominated vegetation types within the watershed. As defined by *King et al.* [2008] for WGEW, "shrub dominated" indicates 20% or more of site vegetation cover contributed by *Acacia constricta* Benth., *Flourensia cernua* DC., and/or *Larrea tridentata* (Sessé and Moc. ex DC.) Coville. "Grass dominated" indicates less than 15% of site vegetation cover contributed by shrubs, primarily species other than *Acacia*, *Flourensia*, or *Larrea*.

3. Data Collection Methodology

3.1. Transect Data

[9] Vegetation data were collected by the line intercept method [*Bonham*, 1989], in which a measuring tape was stretched between the end stakes of a transect line and vegetation crossing the line was measured. In 1967, both basal and canopy cover of shrub and half-shrub (suffrutescent) vegetation were measured to the nearest 3 cm (0.1 ft), and basal cover only was measured for herbaceous vegeta-

Table 1. Selected Examples of Polygon Labels, Text Description, and Map Vegetation Classes for the Vegetation Map[a]

Polygon ID	Cover Label	Description	Vegetation Class
78	Shrub grass	White thorn, creosote, sumac shrubs, black grama, bush muhly grass, nolina, yucca forbs	Shrubs with grass
79	Tree shrub grass along drainage	Mesquite, willow, sumac tree shrubs with grama grasses along drainage ways	Trees and shrubs along channels
80	Open or built-up area	Nonvegetated open or built-up areas; no vegetation classes	Built-up or disturbed
82	Grass with scattered shrub	Black grama, sideoats grama, L. lovegrass grasses (30% cover) scattered creosote, mesquite, yucca	Grass and scattered shrubs
90	Grass	Sideoats and hairy grama, plains lovegrass grasses (20–30% cover) yucca, nolina, ephedra slopes	Grass
116	Shrub grass on rocky soils	Creosote, tarbush, whitethorn shrubs, medium density grama grasses very rocky surface	Shrubs with grass
128	Shrub with sparse grass	Creosote, whitethorn, tarbush shrub with sparse grama grasses and forbs	Shrubs and sparse grass
131	Sparse shrub and grass	Sparse whitethorn, tarbush, creosote with some grama grasses on gravelly upland soils	Shrubs and sparse grass

[a]For the vegetation map, see Figure 3. The full list of polygon information is available at http://www.tucson.ars.ag.gov/dap/.

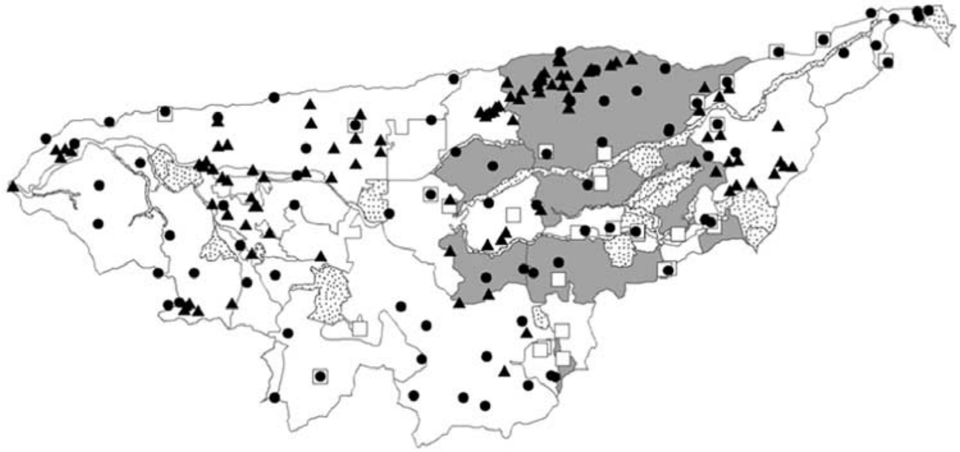

Figure 4. Vegetation map validation data locations and results. Vegetation data used in map validation: open square, prominence data site; circle, transect site; triangle, reconnaissance site. Stippled polygons were not evaluated because of lack of data. Shaded polygons appeared to be topographically and vegetationally complex and will need to be subdivided into more uniform areas.

tion to the nearest 3 mm (0.01 ft). Individual plants were identified to species level where possible and each plant's canopy and/or basal intercept value was recorded on a data sheet.

[10] Beginning in 1994, canopy cover only was collected for all life forms by recording the start and end intercept of each plant to the nearest 1.5 cm (0.05 ft). Because basal cover was not measured after 1967, intercept data from 1967 and later for herbaceous plants cannot be compared directly. Starting in 1994, plant height and diameter perpendicular to the transect line were also measured and recorded to the nearest cm. All measurements excluded branches or inflorescences that protruded from the main volume of the plant's crown, and intercept values were adjusted to remove large gaps in canopy. In subsequent years, additional criteria were specified to remove gaps larger than 5 cm in canopy, and not to record plant intercepts of less than 1 cm.

[11] Most of the vegetation data were collected between June and September, as the predominantly C4 grass species at WGEW grow in response to summer monsoon rains. Shrub and half-shrub identification is possible over a longer period during the year. In 1994, 1998, 1999, and 2005, data were collected as late as October through December. Grazing at transect sites by domestic and wild herbivores could occur at any time throughout the year, and could affect herbaceous canopy measurements from 1994 and later.

[12] Beginning in 1994, point ground cover was observed at 30 cm (1 ft) intervals along the transect tape and recorded as bare ground, rock, litter, or plant crown, for a total of 100 observations per transect line. The amount of observed litter may have been affected by the timing of data collection, especially when observations were made after herbaceous plant senescence in the fall.

3.2. Vegetation Map

[13] Polygons of apparent uniform vegetation type were delineated on air photos and digitized into GIS format. Limited fieldwork was performed in 2002 to acquire additional information on polygon vegetation or land use. Minor editing of the GIS data was later performed to clean up digitizing errors and label a few polygons without attributes.

4. QA/QC

4.1. Transect Data

[14] After collection, data were transcribed from field data sheets to computer spreadsheets. Herbaceous basal cover and shrub/half-shrub canopy cover were transcribed from 1967 data sheets several years after data collection. Quality control procedures included checking minimum and maximum plant intercept values for unrealistically small or large numbers. Extreme values were adjusted to produce plant intercepts consistent with other individuals of the same species. Species identifications were checked for spelling errors, and older names were updated to current botanical standards. For the final database, all nomenclature was updated to conform to the USDA NRCS PLANTS database (2005; available at http://plants.usda.gov/). Ground cover data were verified to have 100 observations per transect line.

4.2. Vegetation Map

[15] A number of data sources were used to validate the map. Validation fieldwork was performed in 2003 and 2006 at 32 locations (22 map polygons) to record and rank vegetation species using a rapid assessment protocol. Reconnaissance field data were obtained in 2003 to characterize the dominant vegetation type at 101 locations (14 polygons). GPS coordinates were recorded for all locations. Vegetation transect data from 1994 or later were used for 84 locations (32 polygons) (Figure 4).

[16] The rapid assessment protocol was derived from the Braun-Blanquet scale method [*Bonham*, 1989], in which a list of species observed is made for the site or "relevé." A prominence rating is assigned to each species, which integrates its estimated dominance, biomass, and commonness. Prominence can be considered the most important part of vegetation description for mapping purposes and can be used quantitatively across several samples or relevés to compute statistics on species [*Rowlands*, 1994]. Prominence ratings and their descriptions are shown in Table 2.

Table 2. Prominence Scale for Ranking Vegetation Species in Relevé[a]

Rating	Status	Description
5	Dominant	Uniformly distributed throughout stand; clearly the one single dominant species
4	Codominant	Uniformly distributed throughout stand; shares dominance with other species
3	Associate	Common throughout stand, but not dominant; easily observed everywhere in stand
2	Uncommon	Sparse; represented by few individuals (~2–12) with coverage usually <1%. Requires searching stand to find; may be erratically distributed
1	Rare	Represented by very few individuals (~1–2); requires searching to find

[a]Scale is after *Rowlands* [1994].

[17] When validation data were pooled, 36 of the 64 vegetated polygons were represented. A few large polygons had as many as 44 data locations (Figure 4); 28 smaller polygons had no validation data, in many cases because of difficulty of field access to areas with substantial topographic relief.

[18] Map accuracy was estimated at 81% at the vegetation class level (29 correctly labeled polygons out of 36 sampled). Seven polygons, located in areas of topographic and edaphic complexity, were incorrectly labeled and will require further study (shaded in Figure 4). An example is the large polygon on the northern watershed boundary (Figure 4, top right; polygon ID 78 in Table 1) labeled "shrub grass," denoting a grass understory in a shrub-dominated area. More than half of the polygon validation points (26/44) were observed in grass-dominated areas. Field observations showed this area to be largely a complex mosaic of grass-dominated slopes flanking shrub-dominated ridge tops that represent different vegetation classes. Additional work will be required to update and completely validate the vegetation map, including fieldwork in the 28 unsampled polygons and in large polygons containing multiple vegetation types.

5. Data Availability

5.1. Transect Data

[19] Vegetation transect data are available in a Microsoft Access database that includes approximately 24,000 plant measurement records and a table of species nomenclature and botanical authority. Data collected 1996–1998 and 2000 were lost during personnel and computer changes, so are not currently included in the database. Ground cover data from 1994, 1995, 1999, and 2005 are available in a Microsoft Excel spreadsheet. Transect data including ground cover are available at http://www.tucson.ars.ag.gov/dap/.

5.2. Vegetation Map

[20] The current WGEW map can be downloaded in shapefile format at (http://www.tucson.ars.ag.gov/dap/). Validation data are available in shapefile and spreadsheet format by request.

5.3. Other Data

[21] Copies of additional vegetation-related data are available by request from the USDA ARS SWRC. These include a GIS vector file of transect site locations (Figure 1); original field data sheets from 1967 with supplementary notes; data entry spreadsheets; repeat photography of the transect sites; and additional repeat photography of other parts of Walnut Gulch from U.S. Geological Survey and Arizona Historical Society archives. Complementary information is also available about WGEW meteorology and soil moisture [*Keefer et al.*, 2008], sediments [*Nichols et al.*, 2008], and rainfall and runoff [*Goodrich et al.*, 2008; *Stone et al.*, 2008].

6. Examples of Research

[22] The WGEW vegetation data will be used as part of ongoing research on hydrological and soil processes as well as directly informing ecological studies; examples are given below. In addition, this kind of accurate information about vegetation cover and composition is needed by land managers who seek to alter vegetation via grazing strategies in southwestern semiarid grasslands.

[23] Generalized vegetation data have previously been used to parameterize models in the WGEW area. *Hernandez et al.* [2000] and *Miller et al.* [2002] used regional land cover maps to model potential impacts of land cover change on rainfall-runoff. *Goodrich et al.* [2005] modeled wildfire impacts using maps of land cover and vegetation type. *Heilman et al.* [2003] used vegetation information derived from NRCS ecological site descriptions for WGEW in modeling tradeoffs between the cost of sediment control and economic return from stocking rates. These types of models could be refined and developed for subwatershed areas using WGEW vegetation data that quantify landscape spatial heterogeneity.

[24] Vegetation dynamics and resulting impacts on erosion and sedimentation in semiarid grasslands will continue to be important topics of research [*Peters et al.*, 2004]. Much additional work needs to be done to understand the correlation of historical and current vegetation distribution and abundance with interacting factors such as precipitation variability, climate change, soil properties, and human impacts [*Gibbens et al.*, 2005]. See *Kidwell et al.* [1998] and *King et al.* [2008] for preliminary ecological studies that used the WGEW data to describe short- and longer-term vegetation trends in relation to precipitation patterns.

[25] The contrast of hydrological and other surface properties between vegetation types (e.g., shrub versus grass dominated) at WGEW has been examined by a number of researchers; some recent publications include *Hogue et al.* [2005], *Nearing et al.* [2005], and *Nichols* [2006]. The vegetation map and long-term database of vegetation measurements will make valuable contributions to the kinds of hydrological and soil research projects mentioned here, both at WGEW and in the surrounding region.

[26] **Acknowledgments.** The authors are indebted to numerous field assistants, past and current staff at the Tombstone facility, land owners in the WGEW, research leaders at the SWRC, colleagues at the University of Arizona and the Jornada Experimental Range, and J. L. Gardner. Use of trade names in this report is for information purposes only and does not constitute an endorsement by the USDA ARS.

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