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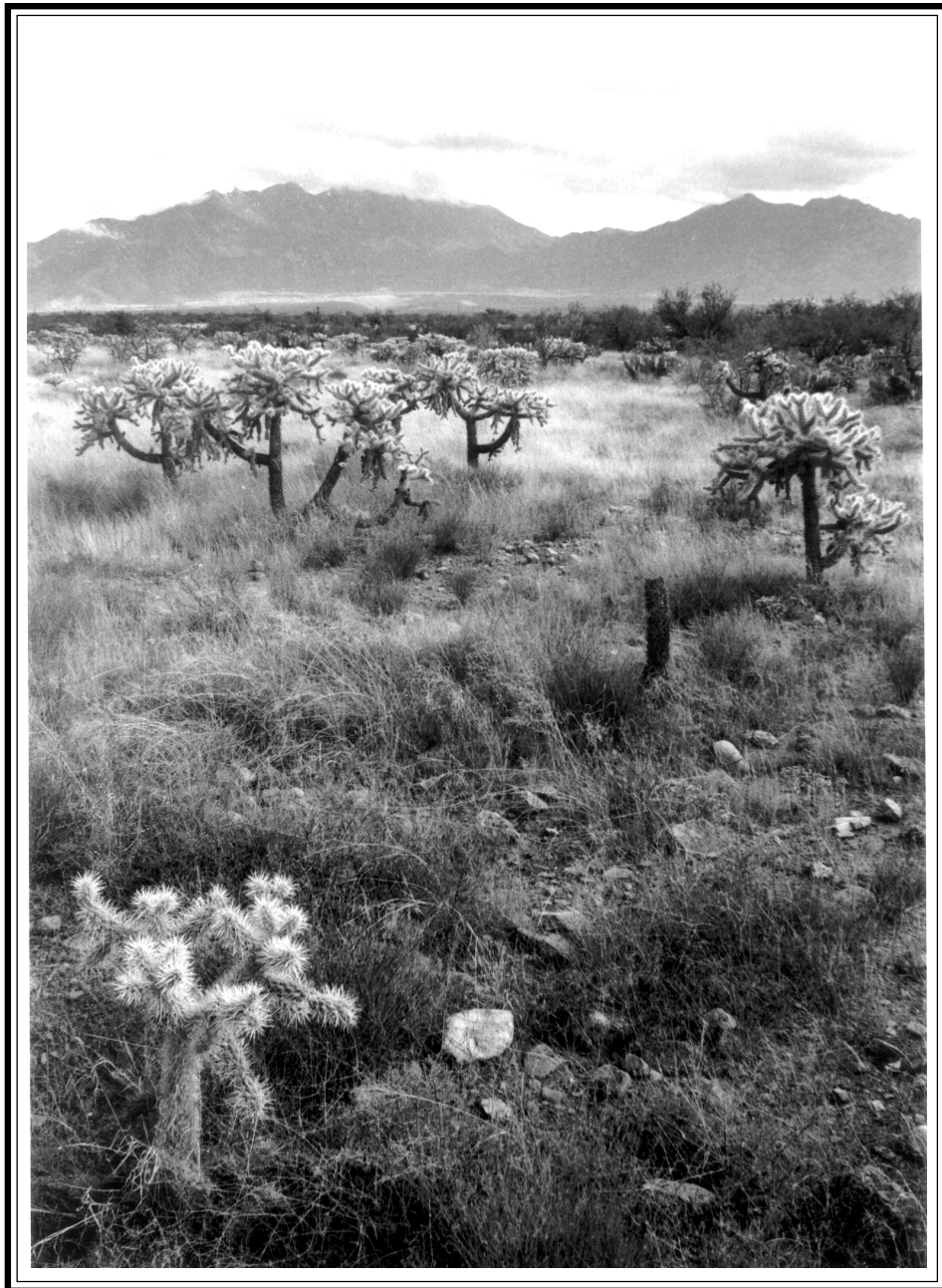
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# Santa Rita Experimental Range Digital Database: User's Guide

Mitchel P. McClaran  
Deborah L. Angell  
Craig Wissler



## Abstract

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Long-term measurements and repeat photograph collections have been collected in a systematic manner on the approximately 21,000 ha Santa Rita Experimental Range (SRER) since its establishment in 1903. This research facility, located in the Desert Grassland vegetation of southern Arizona, was administered by the U.S. Department of Agriculture until 1988, when it was transferred to the State of Arizona to be administered by the University of Arizona, College of Agriculture and Life Sciences. To facilitate the preservation of the long-term data collected on the SRER and to increase access to the data, we developed a digital archive that is accessible on the World Wide Web at <http://ag.arizona.edu/SRER>. The digital archive contains 10 databases, seven of which provide the longest records of ongoing measurements of precipitation, vegetation response to grazing and mesquite clearing experiments, and widespread photographic evidence of landscape changes available for the SRER. Two databases provide essential ancillary data about plant species names and spatial coverages (maps) of elevation, soils, plot locations, and other attributes. The final database is a digital version of a previously published annotated bibliography of SRER publications between 1903 and 1988. The information in these databases is available in five formats (ASCII text, Excel spreadsheet \*.xls, ARCINFO \*.e00, tagged image \*.tif, and graphical interchange \*.gif) that can be easily used in analytic, word processing, graphic, and geographic information system software.

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**Keywords:** long-term ecological data, precipitation, repeat photography, spatial data

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# **Santa Rita Experimental Range Digital Database: User's Guide**

**by Mitchel P. McClaran, Deborah L. Angell, and Craig Wissler**

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# **Santa Rita Experimental Range Digital Database: User's Guide**

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## **Introduction**

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Long-term ecological data provide the opportunity to place current conditions in a historical context. By documenting long-term patterns, the current conditions can be judged as anomalous, average, or unusual. Further, by compiling long-term ancillary information on weather and land use, one can begin to interpret the factors influencing those ecological patterns and how those relationships may have changed over time.

The utility of long-term ecological data is limited by a small number of databases and poor access. We addressed these issues by preserving some existing paper databases in digital format, continuing the collection of data for others, and making them all available to a large number of potential users. In addition, we compiled ancillary data that will assist in interpreting the factors contributing to the long-term ecological changes.

Several of the databases in this archive began as ecological experiments evaluating vegetation manipulations (mesquite removal) and livestock grazing management (season of use and stocking rate). Those experimental designs provide greater opportunities to understand the factors influencing long-term changes than would less structured locations of long-term measurements. In some cases, both the treatments and the measurements have continued. In other cases, the treatments were changed, the measurements were discontinued, or both. When the treatments were continued, they enabled a reassessment of the initial findings following a longer period of application. Whether continued or not, the compilation of these databases facilitates reanalysis using statistical and spatial analysis methods that were unavailable or unconventional 20 to 30 years ago. Such reexaminations are critical to contemporary management because they can validate, reject, or revise long-held assumptions that were based on the initial findings.

These databases are available in digital formats so that they can be easily updated and integrated into computer-based analytical, graphical, and word-processing software. They are made accessible on the World Wide Web at <http://ag.arizona.edu/SRER> for the scientific community, land managers and planners, and the lay public. It is our intention to regularly update these databases as new information is collected. The ability to provide nearly indiscriminate access to this information via the World Wide Web was our greatest motivation to complete this project because it helps fulfill the promise and potential of publicly funded research.

## **Database Management, Access, and Acknowledgment Policies**

The objectives of the Santa Rita Experimental Range Digital Database are to provide broad access to the long-term ecological data available from this research facility and to establish protocols for managing additions to the digital database.

Rigorous error checking was performed on the numeric data from long-term studies and precipitation records. Backup copies of the numeric data files are stored on floppy disks. Updates and additions to the database will be announced in an update log within the database. Access to the database is available through the Web site (<http://ag.arizona.edu/SRER>), and the databases are provided in the most simple and generic formats to maximize the breadth of potential users.

Users are requested to acknowledge their use of the database in publications, research proposals, Web sites, and other outlets with the following statement: "Data

sets were provided by the Santa Rita Experimental Range Digital Database. Funding for the digitization of these data was provided by USDA Forest Service Rocky Mountain Research Station and the University of Arizona.” In addition, where appropriate, users should reference the Web site and this User’s Guide in the literature cited sections of publications. Finally, users are requested to send two copies of any publication that cites this Database to: Mitchel McClaran, School of Renewable Natural Resources, 325 Biological Sciences East Building, University of Arizona, Tucson, AZ 85721.

## Santa Rita Experimental Range

Approximately 40 km south of Tucson, AZ, the 21,500 ha Santa Rita Experimental Range (SRER) is near the northwestern edge of the Desert Grassland vegetation (McClaran 1995) that is common in the Southwestern United States and Northern Mexico (fig. 1). The elevation ranges from 900 to 1,300 m on the western bajadas skirting the Santa Rita Mountains that crest at approximately 2,600 m. Average annual precipitation (250 to 500 mm per year) on the SRER increases with elevation, and approximately 50 to 60 percent occurs during the hot summer months of July through September. The mean annual temperature is approximately 16 °C, with freezing temperatures occurring 20 to 40 nights in the winter, and summer daytime temperatures regularly exceeding 35 °C.

Established in 1903, the SRER is the oldest continuously operating range experiment station in the world (Box and Traylor 1990; Chapline and others 1944; Griffiths 1904). Initially, the U.S. Department of Agriculture Bureau of Plant Industry and the University of Arizona were the primary organizations performing research. In 1915, the U.S. Department of Agriculture Forest Service (Medina 1996) assumed the administration and lead research responsibility. This 73-year era of Federal leadership ended in 1988 when Federal legislation transferred the SRER to the State of Arizona to become part of the land base administered by the Arizona State Land Department. Arizona Senate Bill 1249 (38th Legislature) provided that the area would be used by the University of Arizona for “ecological and rangeland research purposes... until such time as the legislature determines the research use can be terminated on all or part of the lands.” Since that time, the Land Department has overseen its immediate administration by the University of Arizona, College of Agriculture and Life Sciences.



**Figure 1**—Location of Santa Rita Experimental Range in Arizona, U.S.A.

Early research focused on establishing livestock management practices that could be sustained by the wild vegetation. The initial investigations to determine the productive potential of the area required the removal of livestock from 1903 to 1915 to allow recovery from the damage caused by uncontrolled grazing (Griffiths 1904).

Over time, the topics of research broadened to include wildlife, soils, watershed management, vegetation management, entomology, and basic ecology performed by faculty, government scientists, and graduate students from around the United States and the world (Medina 1996). Currently, cattle grazing (approximately 600 animals per year) occurs on over 90 percent of the SRER, and investigations of stocking rate and season of use by cattle are ongoing. Long-term investigations of vegetation change, soil erosion, and termite and small mammal dynamics are continuing. In addition, the number of short-term investigations of plant and animal ecology varies from 30 to 40 per year.

Increasingly, the value of the SRER will expand from a purely research orientation to include the provision of a relatively large and unfragmented wild area on the fringe of the rapidly expanding Tucson metropolitan area. The values from this juxtaposition include recreational opportunities for humans and habitat for sensitive and endangered species. The SRER currently provides habitat for the Federally designated endangered Pima pineapple cactus (*Coryphantha scheeri robustispina* (Schott in Engelm.) L.D. Benson), and it is likely that the endangered lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*) and southwestern willow flycatcher (*Empidonax traillii extimus*) can be found on the SRER at some times in the year.

The coordination of research activities, recreation, and endangered species habitat will be a recurring challenge in the future. Probably a greater challenge will come from the future increase in residential development on land surrounding the SRER. Special care will need to be applied to the design and density of those developments and their supporting transportation corridors in order to limit their impact on the ability to perform research activities and protect endangered species habitat.

The vegetation is dominated by Desert Grassland species, but at lower elevations species prevalent in the Sonoran Desert become more common, and at the higher elevations species from the Madrean Oak Woodland become more common. In the Desert Grassland, the common native grasses are Rothrock grama (*Bouteloua rothrockii* Vasey), sideoats grama (*B. curtipendula* (Michx.) Torr.), Arizona cottontop (*Digitaria californica* (Benth.) Henrard), bush muhly (*Muhlenbergia porteri* Scribn.), tanglehead (*Heteropogon contortus* (L.) Beauv.), several threeawn species (*Aristida* spp. L.), and the nonnative Lehmann lovegrass (*Eragrostis lehmanniana* Nees). Common shrub and cactus species are burroweed (*Haplopappus tenuisectus* (Greene) Blake), cholla cactus species (*Opuntia* spp. Mill.), snakeweed (*Gutierrezia sarothrae* (Pursh.) Britton & Rusby), soaptree yucca (*Yucca elata* Engelm.), catclaw acacia (*Acacia greggii* A. Gray), and desert hackberry (*Celtis pallida* Torr.). The most common tree species is velvet mesquite (*Prosopis velutina* Woot.), and less common species are blue paloverde (*Cercidium floridum* Benth.), canyon hackberry (*Celtis reticulata* Torr.), and Emory oak (*Quercus emoryi* Torr.).

Dramatic vegetation changes have occurred on the SRER since its establishment, and those are well documented in the field measurements of vegetation and in the repeat photography collections in this archive. Briefly, velvet mesquite density and cover has increased since 1902 when it was largely limited to stream washes to its present ubiquity (10 to more than 40 percent cover) on most soils and elevations, except clayey soils (Humphrey and Mehrhoff 1958; McAuliffe 1995). The abundance of burroweed and cholla species has expressed several increases and decreases with about 20 years between peaks (Martin and Turner 1977). Native perennial grasses have increased from less than 1 percent cover in the 1950s to 2 to 4 percent cover in 2000 (Angell and McClaran 2001). Starting in the mid-1980s, the nonnative Lehmann lovegrass became the most common perennial grass on the SRER following a dramatic spread from a limited area (about 1 percent of the SRER) that was seeded between 1935 and 1970 (Anable and others 1992).

## Digital Databases

Because written records of climate, vegetation change, livestock use, and experimental land use treatments as well as repeat photography have been collected on

the SRER since as early as 1902, this archive provides a long-term record that is unsurpassed in the Southwest. The archive (at <http://ag.arizona.edu/SRER>) includes a combination of weather records; plant species composition measurements on more than 300 permanent plots; extensive land treatment studies; short-term, usually small-scale tests or observations; and 117 permanent photography stations. More than 450 publications described the results of this research between 1903 and 1988 (Medina 1996), and certainly hundreds more have been published since 1988.

One goal in developing the digital archive of these databases was to increase their accessibility and their currency. We selected a portion of the databases to initiate the digital archive because we did not have the funding to create a digital version of them all. To date, we have created 10 digital databases. Seven of these provide the longest record of ongoing measurements of precipitation, vegetation response to grazing and mesquite clearing experiments, and widespread photographic evidence of landscape changes available for the SRER. Two of the databases provide essential ancillary data about plant species names and spatial coverages (maps) of elevation, soils, plot locations, and other attributes. The final database is a digital version of Medina's (1996) annotated bibliography of the SRER publications between 1903 and 1988.

The precipitation database includes (1) monthly measurements at a total of 75 rain gauges on the SRER starting as early as 1922, (2) the location of gauges using UTM (Universal Transverse Mercator) coordinates, and (3) the history of name changes and record of longevity for the gauges.

Five databases include measurements of vegetation (cover, biomass, and/or density by species) for locations used in four experiments established by S. Clark Martin. Three of those experiments began in the 1950s and proceeded for approximately 10 years, with annual measurements of cover and biomass on permanently established plots. The experiments were designed to compare vegetation responses to different seasons of livestock grazing, the removal of velvet mesquite, and the spatial distribution of water developments for livestock use. The fourth experiment used a subset of the permanent plots from the previous three experiments and 30 newly established permanent plots to compare, on a large scale, the vegetation responses to continuous-yearlong grazing versus a three-pasture rotation grazing system called the Santa Rita Grazing System. This experiment lasted from 1972 to 1984, with measurements made every 3 years. Mitchel McClaran and his graduate students and assistants at the University of Arizona continue to measure cover and density every 3 years since 1991 on the plots used in the Santa Rita Grazing System experiment. This compilation of databases provides a long-term (more than 40 years) record of vegetation measurements completed at 1 to 7 year intervals on 132 permanent study plots.

A digital collection of repeat photography made at 117 locations on the SRER provides a striking visual record of vegetation, soil erosion, and land use changes since 1902. For 16 locations, Griffiths took the earliest photographs between 1902 and 1905 during his early work on the SRER (Griffiths 1904). The repeat photography series for many locations was initiated between the 1930s and 1950s in conjunction with vegetation manipulations including mesquite clearing, soil erosion control, and livestock exclosures. About half of the locations have a series of repeat photographs taken in only a single direction. The other half include photographs taken in more than one direction and some with three, four, and a maximum of seven directions creating a 360 degree panorama at one location. These multiple directions provide an estimate of the generality of changes (Rogers and others 1984) that is not possible when the photographs are limited to a single direction. The interval between photographs is approximately 15 to 20 years, but within some series the repeated photographs were made twice a year over 5 to 8 years. Nearly all locations were rephotographed between 1998 and 2000 by Mitchel McClaran and his graduate students and assistants at the University of Arizona. These frequencies of repeat photographs enable estimates of seasonal and annual variation in biomass production, long-term successional trends, and longevity for short and long-lived plant species. Approximately 200 repeat photograph locations were discontinued before the 1970s. Those images were not included in this digital archive but they can be accessed through the lead author.

The ancillary database for plant species names provides the genus, specific epithet, and authority names for all species included in the other digital databases. In

addition, there is a translation of the species codes used in those databases and a synonymy table to assist in understanding scientific name changes.

The ancillary database of spatial coverages provides the raw data to generate a geographic information system (GIS) for the SRER. The spatial coverages include (1) SRER boundaries, headquarters, roads, rain gauges, pasture fences, and live-stock water locations, (2) boundaries of the relevant U.S. Geological Survey (USGS) topographic maps and digital elevation models, (3) 1996 Soil and Ecological Site Surveys by the Natural Resources Conservation Service, and (4) permanent transect locations included in the individual studies and the long-term vegetation measurement databases. These coverages enable users to examine spatial patterns in the long-term vegetation and precipitation records, as well as the ability to produce maps of these attributes.

The digital version of Medina's (1996) annotated bibliography is included because it allows the user to remotely access this collection of citations in the same virtual environment that includes databases containing some of the original data referenced in those publications.

## Accessing the Databases

All the digital databases can be accessed on the World Wide Web at <http://ag.arizona.edu/SRER>. The College of Agriculture and Life Sciences, University of Arizona, maintains this Web site and will continue that maintenance indefinitely. Some of these databases are being used in many classes taught at the University of Arizona.

The digital files are in five formats, all of which can be downloaded from the Web site. The text files are in ASCII format so that they are compatible with the maximum variety of word processing programs. The numerical data files are in the Microsoft Excel spreadsheet format (\*.xls) because it has become a standard for organizing numerical data, and the files can be converted into a variety of more powerful database software formats. The spatial coverage (map) files are available as ARCINFO export files (\*.e00) that can be incorporated into geographic information systems for the purposes of constructing maps or performing analyses of spatial patterns. Finally, the repeat photography catalog provides the option to download images in the tagged image format (\*.tif) or to copy images in the graphical interchange file format (\*.gif). Files from both of these formats can be incorporated into image processing software.

It is possible to print or cut and paste images and text directly from the Web site. This is especially relevant for the annotated bibliography and the repeat photography databases.

## Database Catalog

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This catalog includes a brief description of the digital format information found in each of the 10 databases. The descriptions include the topic of the data and the format and general arrangement of the data files. In addition, it describes the availability of metadata files that further describe the data.

### Precipitation

This database includes the Excel format file of numerical data, accompanying metadata files in ASCII text format, an ASCII text file of the rain gauge UTM coordinates, and an ASCII text file describing the name changes for some of the rain gauges. A total of 75 gauges are included in the database, but only 28 are still measured regularly. The frequency of measurement is monthly, and the precision is 0.01 inch. The earliest measurements began in 1922, and 15 gauges have a record from that point to the present. Of the currently measured gauges, 23 have a record of at least 50 years. The locations of the gauges were digitized from locations marked on USGS topographic maps of the SRER. The UTM coordinates represent the digitized points reprojected to the NAD83 datum using the GRS1980 spheroid.

## Plant Species Names

This database includes ASCII text files of (1) the genus, specific epithet, and authority names for taxa identified during measurements made for the ecological studies included in the archive, (2) the translation of species codes used in the Excel format data files for these ecological studies, and (3) an ASCII text file describing some synonymous scientific names for those used in the database.

A total of 102 plant species and 42 species grouped by genera are included in the archive. Perennial species dominate the list because researchers placed less emphasis on annual species, except during biomass measurements. Tree, shrub, and grass identification by the field personnel was reliable, although difficulties in distinguishing some species led to the lumping of species into a single generic group. The lumping of threeawn grass species into an *Aristida* group is the best example of this practice. This list does not represent a flora for the SRER because annual species were not always recorded, and the measurements of vegetation for the ecological studies were restricted to relatively small plots (for example, 1 foot by 100 feet).

## Forest Service Study *FSRM 1706-09*: A comparison of vegetation responses to grazing yearlong, in the growing season, and in the dormant season on low-value semidesert grass-shrub ranges in southern Arizona

This database includes (1) the Study Plan (ASCII text file), (2) citations for publications that resulted from these data (ASCII text file), (3) cover measurements of vegetation by species or species group made on the study transects between 1957 and 1966 and in 1970 (Excel data file and ASCII text files of data layout and notes), (4) biomass production of vegetation by species or species group made on the study transects between 1957 and 1966 and in 1970 (Excel data file and ASCII text files of data layout and notes), (5) biomass production of vegetation by species or species group made on study transects between 1967 and 1969 and in 1971 (Excel data file and ASCII text files of data layout and notes), (6) UTM coordinates for the study transects (ASCII text file), (7) the soil type and distance to livestock water for study transects (ASCII text file), and (8) the history of name and location changes for some study transects (ASCII text file).

S. Clark Martin designed this study to compare plant cover and biomass production among three livestock grazing treatments, three distances from livestock water developments, two mesquite removal treatments, and two soil types (see Study Plan ASCII text file). The grazing treatments were yearlong, dormant season (November through May), and growing season (June through October). The distances from water were 0.25, 0.625, and 1.0 mile from water, which provided a surrogate for grazing intensity. Complete removal and no removal were the mesquite treatments. Coarse sandy loam with low concentration of clay and loamy soil with higher concentrations of clay were the two soil types.

The 72 permanently established study plots were equally divided among six pastures (12 per pasture in Pastures 2N, 3, 5N, 5S, 6B, and 12B). There were two replicates (pastures) devoted to each grazing treatment. The stocking rate of livestock was set to maintain a 40 percent use of perennial grasses in all pastures. Within each pasture, the locations of the 12 plots were nested within the distances from water, soil types, and mesquite treatments (all mesquite were removed from half of each plot) to produce a split-split-split plot experimental design.

On each plot, two parallel 100-foot transects were permanently established, one in the mesquite-cleared area and the other 150 feet away in the mesquite-untreated area. On each of the transects, plant cover was measured as the intercept by species along a graduated tape in increments of 0.01 foot. Perennial and annual grass biomass was measured at the end of the summer growing season by clipping, drying, and weighing (to nearest gram) all grass plants in two 8 foot by 24 foot plots placed along each 100-foot transect.

Based on the transect locations marked on aerial photographs, estimates of these locations were placed on mylar overlays of USGS 7.5' (1:24000) topographic quad maps of the SRER, and then digitized from the overlays. The UTM coordinates represent the digitized points reprojected to the NAD83 datum using the GRS1980 spheroid. During the course of the study, five plot locations were changed.

The results of the study are described in four publications. Cover and production measurements were continued on 60 of these study transects in “Forest Service Study *FSRM 1706-25*: Benefits of rest March–October two years out of three” (see below). Fifty-eight of those study plots are included in the “Continuing remeasurement of selected transects...” made between 1991 and 2000 (see below).

### **Forest Service Study *FSRM 1706-12*: A comparison of vegetation and grazing capacities on mesquite-free and mesquite-infested semidesert ranges in southern Arizona**

This database includes (1) the Study Plan (ASCII text file), (2) citations for publications that resulted from these data (ASCII text file), (3) cover measurements of vegetation by species or species group made on the study transects between 1957 and 1966 (Excel data file and ASCII text files of data layout and notes), (4) cover measurements of vegetation by species or species group made on the study transects between 1953 and 1956 and in 1970 (Excel data file and ASCII text files of data layout and notes), (5) biomass production of vegetation by species or species group made on the study plots between 1957 and 1966 (Excel data file and ASCII text files of data layout and notes), (6) biomass production of vegetation by species or species group made on study plots between 1954 and 1956 and between 1967 and 1971 (Excel data file and ASCII text files of data layout and notes), and (7) UTM coordinates for the study transects (ASCII text file).

S. Clark Martin designed this study to determine the vegetation response to large-scale mesquite removal. It employed four pastures: on two pastures (1 and 7) all mesquite trees were killed with diesel oil; and on two pastures (8 and 10), the mesquite trees were left intact as control, or comparable, study sites. Twenty permanently established study plots were located in each pasture (see Study Plan ASCII text file). The experimental treatments were continued from 1957 through 1966. Livestock use was controlled to contain utilization below 40 percent. In alternate years, livestock use was yearlong, and the following year it was excluded during the summer seasons only. Yearlong grazing continued throughout the study in a fifth pasture (9), which was measured for comparative purposes in 5 of the 10 years.

Estimates of cover by species were made along 100-foot transects by stretching a graduated tape between permanently placed rebar stakes in the ground at either end of the transect. Basal intercept for perennial grasses and canopy intercept for shrubs and trees were measured to the nearest 0.01 foot.

Estimates of grass biomass production for each species were made at the end of each summer growing season using a double-sampling method. Biomass was estimated to the nearest gram on six 9.6 foot by 1 foot plots along each of the 100-foot transects. Clipped plots used for the double-sampling estimates were not located on the permanent transects.

Based on the transect locations marked on aerial photographs, estimates of these locations were placed on mylar overlays of USGS 7.5' (1:24000) topographic quad maps of the SRER, and then digitized from the overlays. The UTM coordinates represent the digitized points reprojected to the NAD83 datum using the GRS1980 spheroid. The results of the study are described in six publications. Cover and production measurements were continued on 20 of these study transects in “Forest Service Study *FSRM 1706-25*: Benefits of rest March–October two years out of three” (see below). Ten of those study transects are included in the “Continuing remeasurement of selected transects...” made between 1991 and 2000 (see below).

### **Forest Service Study *FSRM 1706-15*: A demonstration to determine the feasibility of achieving rotation-deferred grazing within a single pasture by controlling access to water**

This database includes (1) the Study Plan (ASCII text file), (2) citations for publications that resulted from these data (ASCII text file), (3) cover measurements of vegetation by species or species group made on the study transects between 1959 and 1966 (Excel data file and ASCII text files of data layout and notes), (4) biomass production of vegetation by species or species group made on the study plots between

1959 and 1966 (Excel data file and ASCII text files of data layout and notes), (5) UTM coordinates for the study transects (ASCII text file), and (6) distance to live-stock water for study transects (ASCII text file).

S. Clark Martin designed this study to determine the degree to which the availability of drinking water will control the spatial distribution of livestock grazing use. This work was pursued because controlling the distribution of livestock use through the availability of drinking water could be less expensive than building fences.

Permanently established study transects were arranged at five increasing distances from water developments, approximately 100, 200, 300, 400, and 500 m from the water (see Study Plan ASCII text file). Two replications of this series of five plots were established at five water sources in Pasture 6A and one in Pasture 6B, for a total of 60 permanent transects. The water in Pasture 6B was made available to livestock throughout the year. In contrast, availability in Pasture 6A was limited to only one of five water locations at any time, and those locations were switched every 3 months. This spatial arrangement of plots radiating from the water source enabled one to assess changes in the magnitude of grazing use and impact relative to the proximity to water. The degree of livestock use around the continuously available water source provided a control group to assess the patterns around the rotated water locations. Finally, comparisons among the rotated waters enabled an assessment of the degree to which water availability can influence livestock use patterns. The application of these experimental treatments continued from 1959 through 1966.

Estimates of cover by species were made along 100-foot transects by stretching a graduated tape between permanently placed rebar stakes in the ground at either end of the transect. Basal intercept for perennial grasses and canopy intercept for shrubs and trees were measured to the nearest 0.01 foot.

Estimates of grass biomass production for each species were made at the end of each summer growing season using a double-sampling method. Biomass was estimated to the nearest gram on six 9.6 foot by 1 foot plots along each of the 100-foot transects. Clipped 9.6 square foot plots used for the double-sampling estimates for each grass species were not located on the permanent transects.

Based on the transect locations marked on aerial photographs, estimates of these locations were placed on mylar overlays of USGS 7.5' (1:24000) topographic quad maps of the SRER, and then digitized from the overlays. The UTM coordinates represent the digitized points reprojected to the NAD83 datum using the GRS1980 spheroid. The results of the study are described in one publication. Cover and production measurements were continued on 35 of these study transects in "Forest Service Study *FSRM 1706-25*: Benefits of rest March-October two years out of three" (see below). All 35 of those study transects are included in the "Continuing remeasurement of selected transects..." made since 1991 (see below).

## Forest Service Study *FSRM 1706-25*: Benefits of rest March–October two years out of three

This database includes (1) the Study Plan (ASCII text file), (2) citations for publications that resulted from these data (ASCII text file), (3) cover measurements of vegetation by species or species group made on the study transects in 1975, 1978, 1981, and 1984 (Excel data file and ASCII text files of data layout and notes), (4) cover measurements of vegetation by species or species group made on additional transects measured in 1975 (Excel data file and ASCII text files of data layout and notes), (5) density measures of vegetation by species or species group made on study transects in 1972, 1975, 1978, 1981, and 1984 (Excel data file and ASCII text files of data layout and notes), (6) density measures of vegetation by species or species group made on additional study transects in 1974 and 1975 (Excel data file and ASCII text files of data layout and notes), (7) biomass production of vegetation by species or species group made on the study plots between 1972 and 1975 (Excel data file and ASCII text files of data layout and notes), (8) biomass production of vegetation by species or species group made on additional study plots in 1972 (Excel data file and ASCII text files of data layout and notes), and (9) UTM coordinates for the study transects (ASCII text file).

S. Clark Martin designed this study to evaluate the response of vegetation to a three-pasture grazing rotation design where no grazing occurred during two of three summer growing seasons. It expanded the scale of the earlier seasonal grazing research developed in "Forest Service Study *FSRM 1706-09*: A comparison of vegetation responses to grazing yearlong, in the growing season, and in the dormant season on low-value semidesert grass-shrub ranges in southern Arizona" (described above). This larger scale study included 12 pastures compared to only six pastures in the earlier study. This three-pasture grazing design became widely applied by land management agencies in Arizona and was referred to as the Santa Rita Grazing System.

The 12 pastures used in the study were arranged in three sets of four pastures each, where three of the pastures were included in the seasonal rotation and the fourth was grazed yearlong (see Study Plan ASCII text file). The yearlong pastures served as the comparison for the grazing rotation treatment. Two grazing seasons were defined in the rotated pastures: a summer season from March through October and a winter season from November through February. The grazing sequence for a pasture was winter rest > summer graze > winter rest > summer rest > winter graze > summer rest over a 3-year period.

The study used 145 permanently established transects, with 10 transects in each of 10 pastures (Pastures 1, 2N, 2S, 3, 5N, 5S, 8, 12B, 21, and 22), 20 transects in Pasture 6B, and 25 transects in Pasture 6A. Remarkably, 115 of these study plots were used in previous studies, and the continued measurement of vegetation attributes extended the long-term record another 12 years, in most cases from the 1950s to the mid-1980s. Sixty plots that were measured between 1957 and 1971 in Pastures 2N, 3, 5N, 5S, 6B, and 12B were continued from "Forest Service Study *FSRM 1706-09*: A comparison of vegetation responses to grazing yearlong, in the growing season, and in the dormant season on low-value semidesert grass-shrub ranges in southern Arizona." Twenty plots that were measured between 1953 and 1971 in Pastures 1 and 8 were continued from "Forest Service Study *FSRM 1706-12*: A comparison of vegetation and grazing capacities on mesquite-free and mesquite-infested semidesert ranges in southern Arizona." Thirty-five plots that were measured from 1959 to 1966 in Pastures 6A and 6B were continued from "Forest Service Study *FSRM 1706-15*: A demonstration to determine the feasibility of achieving rotation-deferred grazing within a single pasture by controlling access to water." The remaining 30 study plots were first measured in 1972 for this study.

Estimates of cover by species were made along 100-foot transects by stretching a graduated tape between permanently placed rebar stakes in the ground at either end of the transect. Basal intercept for perennial grasses and canopy intercept for shrubs and trees were measured to the nearest 0.01 foot. Estimates of perennial plant density were made in a 100 foot by 1 foot belt transect, where the 100-foot dimension was provided by the permanent line intercept transect location, and the 1-foot width was on the right side of the transect as viewed from the 0-foot marker.

Estimates of grass biomass production for each species were made at the end of each summer growing season using a double-sampling method. Biomass was estimated to the nearest gram on six 9.6 foot by 1 foot plots along each of the 100-foot transects. Clipped 9.6 square foot plots used for the double-sampling estimates for each grass species were not located on the permanent transect.

Based on the transect locations marked on aerial photographs, estimates of these locations were placed on mylar overlays of USGS 7.5' (1:24000) topographic quad maps of the SRER, and then digitized from the overlays. The UTM coordinates represent the digitized points reprojected to the NAD83 datum using the GRS1980 spheroid.

The results of the study are described in one publication. Cover and density measurements are continued on 132 of the study transects in the "Continuing remeasurement of selected transects..." made since 1991 (see below).

## **Continuing remeasurement of selected transects used in Forest Service Studies *FSRM 1706-09, FSRM 1706-12, FSRM 1706-15, and FSRM 1706-25***

This database includes (1) the description of measurement protocols (ASCII text file), (2) citations for publications that resulted from these data (ASCII text file),

(3) cover measurements of vegetation by species or species group made on the study transects between 1953 and 2000 (Excel data file and ASCII text files of data layout and notes), (4) density measures of vegetation by species or species group made on study transects between 1972 and 2000 (Excel data file and ASCII text files of data layout and notes), (5) UTM coordinates for the study transects (ASCII text file), and (6) grazing history of pastures from 1983 through 2000 (ASCII text file).

This database includes all measures of cover and density made on these study transects since they were established during Forest Service Studies *FSRM 1706-09*, *FSRM 1706-12*, *FSRM 1706-15*, and *FSRM 1706-25* (see above). Mitchel McClaran and his graduate students and assistants completed the measurements in 1991, 1994, 1997, and 2000. For many study transects, this database includes 19 remeasurements of perennial plant cover made more than 40 years since the study plot establishment in the 1950s and nine remeasurements of perennial plant density over the nearly 30 years since their initial measurement in 1972.

Estimates of cover by species were made along 100-foot transects by stretching a graduated tape between permanently placed rebar stakes in the ground at either end of the transect. Basal intercept for perennial grasses and canopy intercept for shrubs and trees are expressed in units of 0.1 foot. After 1984, cover was measured in units of 0.1 foot, but earlier measurements were in units of 0.01 foot. This database reports cover measurements to the nearest 0.1 foot for consistency.

Estimates of perennial plant density were made in a 100 foot by 1 foot belt transect, where the 100-foot dimension was provided by the permanent line intercept transect location, and the 1-foot width was on the right side of the transect as viewed from the 0-foot marker.

The UTM coordinates for the study transects were recorded with a Global Positioning receiver in 2000 by Mitchel McClaran when the transects were visited for remeasurement. Therefore, these UTM coordinates are more accurate than the locations estimated from aerial photographs in the other databases. These coordinates are projected in the NAD83 datum using the GRS1980 spheroid.

The grazing history for each pasture from 1983 to 2000 includes the number of animal unit months and the timing of use for each pasture. Earlier grazing records are given in the study plans for the previous "Forest Service Studies *FSRM 1706-09*, *FSRM 1706-12*, *FSRM 1706-15*, and *FSRM 1706-25*" (see above).

Five publications using this extended remeasurement data set are included in the database.

## Spatial Data (Map Coverages)

This database provides the information necessary to reproduce 22 maps of the spatial distribution of four types of data: human structures and boundaries, topography and elevation, soil and ecological sites, and permanent transect locations. These coverages are available as ARCINFO export files (\*.e00). In that format, they can be used in a geographic information system to create simple maps of the spatial distributions or to perform more sophisticated analyses of the spatial relationships among these attributes, such as the distribution of the permanent study plots in relation to soils.

The coverages are projected in the NAD83 datum using the GRS1980 spheroid. There is a metadata file (see metadata ASCII text files) for each coverage that includes (1) date of file construction, (2) characteristics of the projection, (3) data type, (4) description of content, (5) file format, (6) file size, (7) history of file development and sources of data, and (8) attribute definitions and values descriptions in file rows and columns.

To download the ARCINFO export files using Netscape Web browser, right-click the .e00 file link, then left-click *Save Link As . . .* In the *Save As* dialog box, select the location in which to save the file. The name of the .e00 file will display as the *File name*, and the *Save as type* will be *All Files (\*.\*)*. Click *Save*. To download the metadata, right-click the metadata file link, then left-click *Save Link As . . .* The name of the metadata file will display as the *File name*, and the *Save as type* will be *Plain Text (\*.txt)*. Click *Save*.

To download the ARCINFO export files using Microsoft Internet Explorer Web browser, left-click the .e00 file link, then left-click *Save this file to disk*. Click *OK*. In

the *Save As . . .* dialog box, select the location in which to save the file. The name of the .e00 file will display as the *File name*, and *E00 File* will display as the *Save As* type. Click *Save*. To download the metadata, right-click the metadata file link, then left-click *Save Target As . . .* The name of the metadata file will display as the *File name*, and the *Save as type* will be *Text Document*. Click *Save*.

Note that these instructions have been tested using Netscape version 4.77 and Microsoft Internet Explorer version 5.50.

The coverages pertaining to human structures and boundaries will represent the location of human-made structures and political boundaries. The unique coverages are (a) the SRER boundaries, (b) headquarters buildings, (c) roads, (d) rain gauges, (e) pasture fences, (f) water tanks (dirt), (g) metal water tanks (rims), (h) water wells, and (i) electric transmission lines. Coverages of human structures are based on the locations on maps made in the 1980s. It is important to recognize that there have been changes in the number and location of structures since the establishment of the SRER in 1903, and that there will be future changes. Future changes will be noted in the Update log on the Web site.

The coverages pertaining to elevation and topography will represent the topography, slope, and aspect for the SRER from USGS topographic and digital elevation models (DEM). The unique coverages are (a) boundaries for relevant USGS topographic map quadrangles, (b) Green Valley USGS Quadrangle level-2 DEM, (c) Helvetia USGS Quadrangle level-2 DEM, (d) Sahuarita USGS Quadrangle level-2 DEM, (e) Corona de Tucson USGS Quadrangle level-2 DEM, and (f) a mosaic of the four USGS Quadrangle level-2 DEM's clipped to the SRER boundary.

The coverages pertaining to soil and ecological sites represent the results of a 1996 survey (Breckenfeld and Robinett 1997) by the Natural Resource Conservation Service (NRCS). The survey identified and mapped the location of 24 soil series and 21 ecological sites. The unique coverages are (a) 1996 Soil Survey by NRCS and (b) 1996 Ecological Site Survey by NRCS.

The coverages pertaining to the location of permanent study areas and transects represent the location of all study areas used to gather vegetation information during the four Forest Service studies and the continuing remeasurement of these areas. The unique coverages are (a) transect locations for Forest Service Study *FSRM 1706-09*, (b) transect locations for Forest Service Study *FSRM 1706-12*, (c) transect locations for Forest Service Study *FSRM 1706-15*, (d) transect locations for Forest Service Study *FSRM 1706-25*, and (e) transect locations for continuing remeasurement of transects.

## Repeat Photography Collection

This database includes repeat photography images for 117 locations on the SRER, accompanying text written by the photographers that describes the vegetation and other attributes of the scene, and UTM coordinates of the photo station locations. The Web address is <http://ag.arizona.edu/SRER/photos>. Access to photographs and text for a photo station location can be made through the photo station number or from a hyperlinked map of photo station locations on the SRER. Mitchel McClaran recorded the UTM coordinates with a Global Positioning receiver between 1998 and 2000 when repeat photography was performed. The coordinates are projected in the NAD83 datum using the GRS1980 spheroid. The images can be downloaded as tagged image format files (\*.tif) or copied as images in the graphical interchange format file (\*.gif).

The images are accompanied by a Photo Archive number that identifies the location, direction, year, and month of the photograph. For example, the Photo Archive number 45.1.1948.06 identifies the image as being made at photo station 45 (or PS 45), looking in the direction that is closest to north and on the east side of north, in the year 1948, and the sixth month, or June. The direction code ranges from 1 to 7: about half of the locations have photographs taken in only one direction, and about 40 percent have two directions. One location (PS 42) has seven locations that are arranged to provide a 360 degree view. When more than one direction is included for a photo station, the value of 1 was assigned to the direction closest to north on the east side of north, and subsequent values increased in a clockwise direction.

Griffiths took the earliest photographs between 1902 and 1905 at 16 different locations (PS 219, 220, 221, 222, 224, 228, 229, 230, 231, 233, 234, 251, 332, 333, 334, and 335). The average interval between photographs is approximately 15 to 20 years, but some locations have repeat photographs made twice a year for a period of up to 8 years.

## Annotated Bibliography

This database is a digital version of Medina's (1996) compilation of the SRER history and all known publications made between 1903 and 1988 about work completed on the SRER and by SRER researchers. The Web address is <http://ag.arizona.edu/SRER/history>.

The bibliography includes over 450 citations with short annotations about their content. The citations are given in alphabetical order. Four appendices list soils, vertebrates, and plants species known from the SRER, and annotated historical maps.

## Future Efforts

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Updates to the precipitation database will be made approximately every 3 to 6 months, and updates to the "Continuing remeasurement of selected transects used in Forest Service Studies *FSRM 1706-09*, *FSRM 1706-12*, *FSRM 1706-15*, and *FSRM 1706-25*" data set are planned for 2003, 2006, and 2009 following remeasurement of transects in those winter seasons. Updates to the Repeat Photography collection are planned for 2010, about 10 years after the most recent set of photographs.

Efforts will be made: (1) to add more historical data sets to the database and to stimulate the remeasurement of some of the permanent plots associated with those studies, (2) to update the annotated bibliography with publications since 1989, and (3) to create a catalog of ongoing research projects.

All additions and revisions of data sets will be noted in the Update Log on the Web site.

## Acknowledgments

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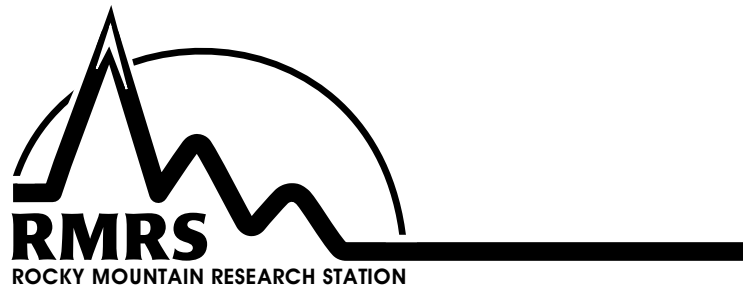
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