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ECOLOGICAL SITES OF THE WALNUT GULCH EXPERIMENTAL WATERSHED

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ABSTRACT: Soil and water conservation efforts on rangelands require a marriage of hydrologic and range management concepts. One important range management concept is that of an ecological site, which is defined by its ability to produce a plant community consisting of certain kinds, amounts, and proportions of vegetation. Multiple soil series can produce the same plant community, and so are associated with a single ecological site. One can create maps of ecological sites using SSURGO soils maps by assigning map units, each consisting of a number of soil series, to the ecological site of the dominant soil series in each map unit. Such maps are too coarse for ranch management. However, these maps might be the only way to apply currently documented range management knowledge in hydrologic models, at least until ecological sites are more widely mapped. The Natural Resources Conservation Service (NRCS) provides written descriptions of ecological sites, including a state and transition model and some information applicable to hydrologic models. We examine the utility of ecological sites for hydrologic research in the context of the Walnut Gulch Experimental Watershed (WGEW), a 150 km^2 research watershed in southeastern Arizona. We illustrate the distribution of ecological sites across the watershed; describe a state and transition model and its management implications for one ecological site, Loamy Upland; list the common ecological sites on Walnut Gulch and present hydrologic information about ecological sites contained in NRCS site descriptions; and explain how to access ecological site information for other locations based on the SSURGO database.
KEY TERMS: ecological sites; rangeland hydrology; rangeland management; SSURGO.

INTRODUCTION

As the Southwest's population grows, the focus of rangeland management will shift. In the past, forage production was the dominant rangeland management objective. Now, open space, recreation, wildlife habitat, and watershed protection increasingly influence land management, especially on public land. Hydrologic objectives of importance include reducing on-site runoff and erosion and off-site sedimentation, as well as the maintaining riparian ecological communities and avoiding flooding and associated expensive infrastructure investments. In rapidly urbanizing watersheds, communities will attempt to maintain natural flow regimes through a combination of designed landscape features in developed areas and vegetation management elsewhere. Hydrologists will increasingly be asked to quantify the hydrologic effect of potential management options as part of integrated efforts to achieve a number of objectives at the watershed scale.

ECOLOGICAL SITE DEFINITIONS AND DESCRIPTIONS

Rangeland managers manage vegetation. Thus, they need a conceptual framework that defines potential vegetation communities, describes how management can shift from one vegetation community to another, and documents the expected benefits provided by the various potential vegetation communities. The most widely used conceptual unit in the range discipline is the "ecological site". The NRCS (2003b, p. 3-1.1) defines an ecological site to be "a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation." In Arizona the NRCS, Bureau of Land Management, Bureau of Indian Affairs, and Arizona State Land Department all use ecological sites in rangeland management. The Forest Service uses a similar concept called an ecological type, and an interagency effort is currently underway to standardize the approaches.

Complete ecological sites have an approved written description. The sites in southeastern Arizona have been under development since the first versions of "range sites" in the 1960s. One significant change over time has been to broaden the range of ecological information contained in the description to support management for objectives other than grazing. Another significant change was the adoption of state and transition models in the place of condition classes that tacitly assumed the potential for a continuous progression through seral stages. Westoby et al. (1989) pointed out that, particularly for arid and semiarid regions, vegetation can enter states that are difficult to change without substantial management inputs.

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Subsequently, there has been a substantial effort to define state and transition models for ecological sites. The NRCS defines a state as "a recognizable, relatively resistant and resilient complex with attributes that include a characteristic climate, the soil resource including soil biota, and the associated aboveground plant communities". A transition is defined as "the trajectory of system change between states that will not cease before the establishment of a new state" (NRCS, 2003b, p. 3-1.3). Some observers note that concepts in state and transition models are still being developed and need to be linked to underlying ecological theory (Briske et al., 2005). In addition to state and transition models with descriptions and pictures of each state, site descriptions also contain information on physiographic, climatic, water, and soil features; a detailed species list; soil and canopy cover; a typical growth curve; interpretations of how the site is used by wildlife, hydrologic response, and recreation potential; and the locations of the site in relatively undisturbed conditions.

Defining ecological sites often requires the difficult task of "drawing lines" through natural gradients. The need to explain ecological site concepts to land managers and the extensive nature of rangelands imply that ecological sites are often "lumped" to a larger degree than if they were defined and described for research purposes. The least disturbed vegetation community found growing on similar soils, slope, climate, and other factors defines the Historic Climax Plant Community (HCPC) for each ecological site. While identifying ecological sites often requires examining soil characteristics in the root zone and knowledge of local soil-water-plant relationships, in many cases the differences between sites are obvious and non-specialists could identify the boundaries based on slope breaks or geomorphic features.

Ecological sites occupy a middle position within a hierarchical land classification system defined by the NRCS. Several soil series are usually grouped to comprise an ecological site, and groups of ecological sites form subdivisions of Major Land Resource Areas. The area in southeastern Arizona around the USDA Agricultural Research Service, Southwest Watershed Research Center, Walnut Gulch Experimental Watershed (WGEW) is a transition zone between the Sonoran and Chihuahuan deserts, influenced by both summer and winter rains. This area, known as Major Land Resource Area (MLRA) 41 Southeastern Arizona Basin and Range, is subdivided into three Common Resource Areas (CRAs) formed by annual precipitation zones: a brush dominated zone (180-300 mm, 41-2AZ Chihuahuan - Sonoran Desert Shrub Mix); a grass dominated zone (300-400 mm, 41-3AZ Arizona Semi-Desert Grassland); and a zone dominated by oak savannah (400-500 mm, 41-1AZ Mexican Oak - Pine Woodland and Oak Savannah). Almost 70 ecological sites are defined within the 3 zones.

It is prudent to mention a few caveats about ecological sites. While ecological sites have been mapped on many ranches as part of NRCS conservation planning, neither sites nor states been widely mapped at the landscape scale. Also, while all western states have defined and described ecological sites, not all site descriptions are up-to-date and complete. In particular, information associated with alternative states is often limited. Over time the format for site descriptions can be expected to change as the scientific tools to support rangeland vegetation manipulation require interdisciplinary research and are still under development (Herrick et al., 2006).

ECOLOGICAL SITES ON WALNUT GULCH

WGEW is located almost completely within the grass-dominated zone (CRA 41-3), except for a small portion in the oak savannah zone at the highest elevations. Figure 1 shows the distribution of ecological sites on Walnut Gulch. The ecological sites were mapped concurrently with a soil survey of Walnut Gulch (Breckenfeld et al., 1995), and to the same standards. Additional information on the geology, geomorphology, and soils of WGEW can be found in Osterkamp (2008).

Limy Upland and a complex comprised of two sites, Loamy Upland and Limy Slopes, are the most extensive sites on WGEW. Limy Upland dominates the northwestern portion of the watershed, including the brush-dominated Lucky Hills study area. Although Limy Upland sites in this CRA have enough precipitation to support grass-dominated vegetation communities, the soils are high in carbonates and coarse textured, and so naturally droughty, favoring brush over grass. The Limy Upland site tends to be dominated by drought tolerant shrubs like creosote (*Larrea tridentata*) and whitethorn acacia (*Acacia constricta* var *constricta* or *paucispina*). Skirvin et al. (2008) classify Lucky Hills in the "Shrubs and sparse grass" category. Grasses comprise up to 30 percent of annual production on undisturbed Limy Uplands sites, and less on areas with a history of grazing. Limy Uplands that have been heavily grazed often produce little forage except annuals in wet winters. Herbicides and fire can increase grass production in the short-run, but soil moisture limitations cause shrubs to return to dominance in the long-run.

The mapping unit consisting of a complex of Loamy Upland and Limy Slopes covers much of the northeastern portion of the watershed, including the grass-dominated study area known as Kendall. Limy Slopes are similar to Limy Upland in having very calcareous soils, although there is a thick, dark colored (mollic) surface over the calcic subsoil. Skirvin et al. (2008) classify Kendall in the "Grass" category. Dominant species on Kendall have included black grama (*Bouteloua eriopoda*), sideoats grama (*Bouteloua curtipendula*), three-awn (*Aristida* sp.) and cane beardgrass (*Bothriochloa barbinodis*) (King et al., 2008). Potential problems with Limy Slopes include invasion by Lehmann lovegrass (*Eragrostis lehmanniana* Nees) or the shrub species dominant on Limy Upland. With long-term erosion, Limy Slopes can lose their mollic cap and degrade to a Limy Upland site with calcic material at the surface. Loamy Upland, found on 1 to 15% slopes, is very prone to invasion by Lehmann lovegrass, as well as mesquite (*Prosopis* sp.). Both Limy Slopes and Loamy Upland have a much greater natural potential to produce grass than Limy Upland, with up to 85% of the annual production on undisturbed sites coming from grass and grasslike species. Brush control measures have a much greater chance of long term success than on Limy Upland, although fires frequent enough to kill small shrubs and trees may be needed to maintain open grasslands.

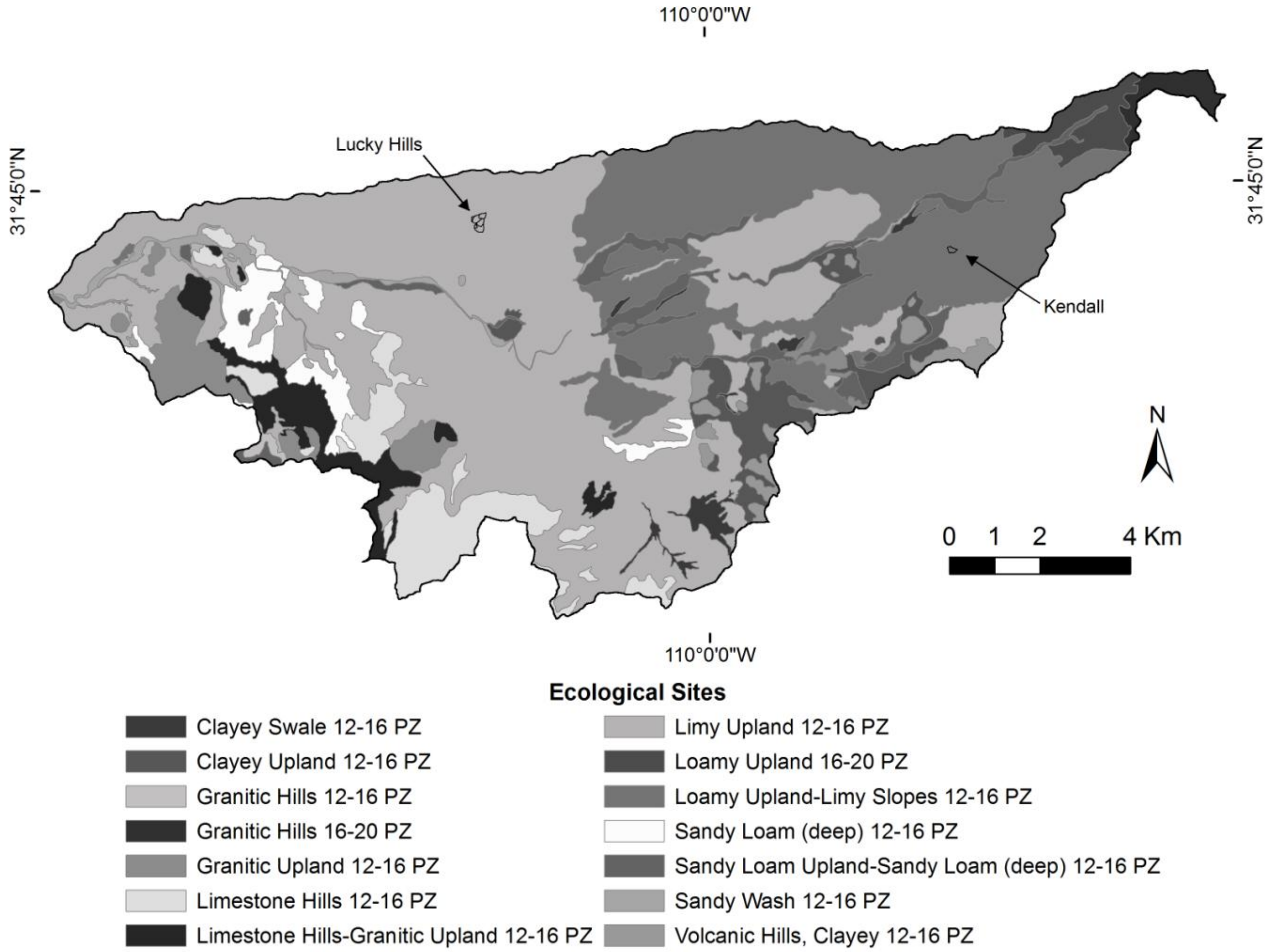

Figure 1. The ecological sites of the Walnut Gulch Experimental Watershed, including the Precipitation Zone (in inches).

A state and transition model for the Loamy Upland ecological site is shown in Figure 2. The model for this site includes 5 states. A sixth state is considered so degraded by soil erosion that it has crossed a threshold and now has a different, less productive, potential plant community. Within the Historic Climax Plant Community state, fire and drought could cause temporary shifts between the three plant communities shown.

By 2006, seed sources for both mesquite and Lehmann lovegrass (Transition 1a) had appeared in the Loamy Upland areas around the Kendall study area. The vegetation was beginning to transition from the HCPC state toward the Mesquite, Lehmann state as small mesquite trees were getting established and Lehmann lovegrass was appearing on ridges. Prolonged drought resulted in high perennial grass mortality prior to the 2006 summer monsoon. Lehmann lovegrass spreads rapidly following drought (Robinett, 1992), and 2006 saw a significant shift toward Lehmann lovegrass and the Mesquite, Lehmann state. Once Lehman lovegrass starts producing seeds it is very difficult to eliminate, even with herbicides. Management objectives for grazing and/or returning to pre-European ecological systems favor attempts to shift from most states toward the HCPC state, if economically justified. However, if the principal objectives are to minimize runoff and erosion, one might favor the Mesquite, Lehmann state, particularly if mesquite cover is limited, as Lehmann lovegrass can produce up to a third more biomass than native grasses, once established.

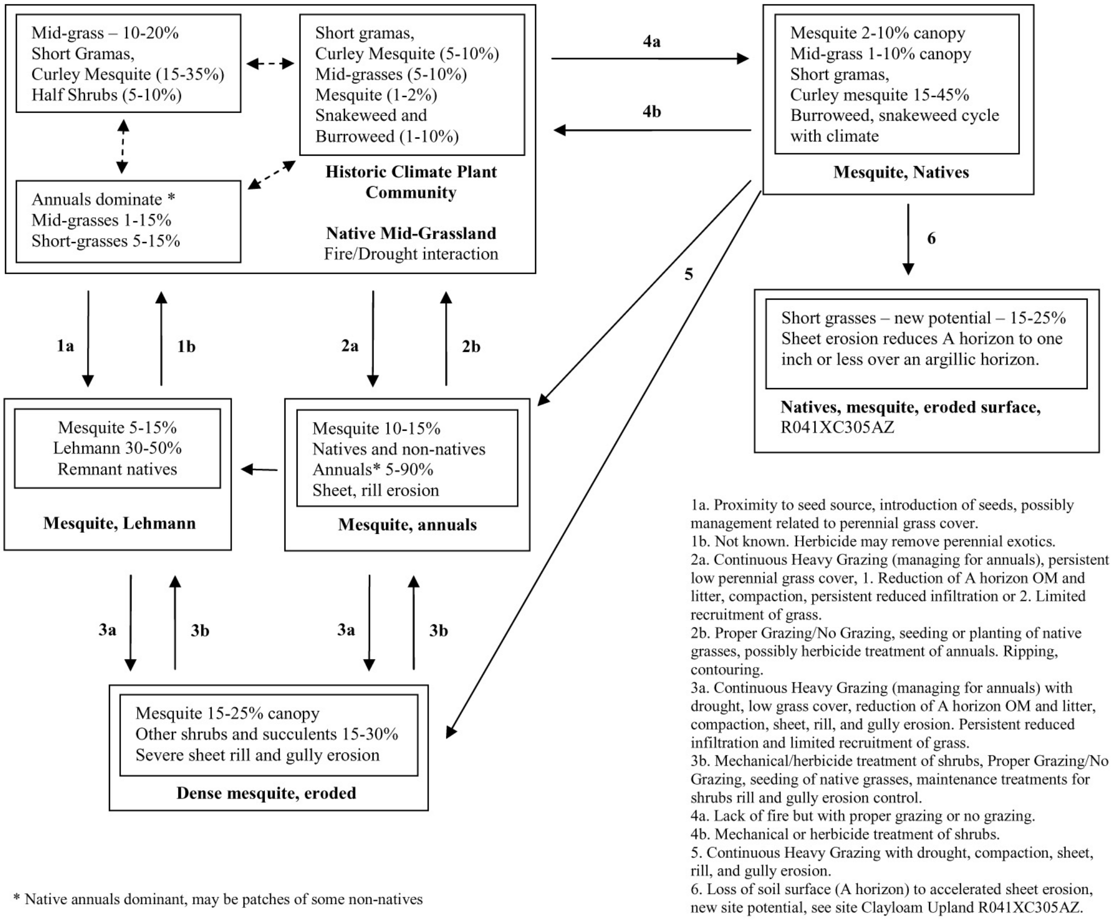

Figure 2. The State and Transition Model for the Loamy Upland Ecological Site.

ECOLOGICAL SITE INFORMATION FOR WATER RESOURCES MANAGEMENT

Given the complex and spatially extensive nature of rangelands, a Geographic Information System (GIS) should be used to manage information on rangelands for water resources. On the WGEW spatial information is available on meteorology, precipitation, runoff, and sediment at selected locations. Channels, watershed boundaries, vegetation and other spatial information as GIS layers are also available (Heilman et al., 2008). The GIS layer for the ecological sites shown in Figure 1 can be accessed at http://tucson.ars.ag.gov/dap/. Table 1 lists some of the salient information of interest to hydrologists for Walnut Gulch from the site descriptions. As a general rule, soils information should come from SSURGO and vegetation information from ecological sites. The WGEW ecological site GIS data layer, and the associated information maintained in the NRCS ecological site descriptions, offer hydrologists interested in understanding management effects on rangelands an opportunity to explore, use, and refine information on ecological sites and their associated soil series.

Additional information for each site can be found in the official descriptions found at the Ecological Site Information System website http://esis.sc.egov.usda.gov/ (accessed 2/10/2010). Site descriptions can be downloaded as approved reports, although most data will have to be extracted manually. A typical application of ecological site information is for the parameterization of simulation models, especially for the annual production of vegetation, as in the Automated Geospatial Watershed Assessment tool, AGWA (http://www.tucson.ars.ag.gov/agwa/; accessed 2/10/2010). Ecological sites have also been used to estimate grazing effects on production, cover and economic returns on Walnut Gulch (Duan, 2005). Both AGWA and the Duan study used the older condition class concept to estimate stocking rates, rather than State and Transition models.

Table 1. Examples of hydrologic information associated with the major ecological sites on Walnut Gulch.

Ecological Site*	Percent of WGEW Area	Corresponding Soil Series	Runoff Class	Available Water Capacity cm/cm	Historic Climax Plant Community		
					Normal Year Annual Production kg/ha	Litter Cover %	Bare Ground %
Limy Upland	46	Grizzle coarse sandy loam Luckyhills loamy sand Luckyhills-McNeal complex Monterosa very gravelly fine sandy loam Sutherland very gravelly fine sandy loam Sutherland-Mule complex Tombstone very gravelly fine sandy loam	Low-Med	0.07-0.21	650	10-20	15-55
Loamy Upland – Limy Slopes	25	Elgin-Stronghold complex McAllister-Stronghold complex Stronghold-Bernardino complex	Low-Med	0.08-0.21	1120	10-60	5-25
Limestone Hills	6	Mabray-Rock outcrop complex	Low-Med	0.06-0.16	910	10-25	5-60
Sandy Loam Upland - Sandy Loam (deep)	4	Baboquivari-Combate complex	Low-Med	0.08-0.2	1190	20-75	10-20
Limestone Hills – Granitic Upland	3	Mabray-Chiricahua-Rock outcrop complex	Low-Med	0.05-0.24	910	10-25	5-60
Sandy loam (deep)	3	Schiefflin very stony loamy sand	Low	0.12-0.2	1130	30-75	10-25
Granitic Upland	3	Chiricahua very gravelly clay Lampshire-Rock outcrop complex	Low-Med	0.05-0.24	670	15-50	5-50

* All listed sites are in Common Resource Area (CRA) 41-3AZ, Southern Arizona Semi-Desert Grassland, with 300-400 mm of average annual precipitation.

Readers interested in using ecological site information to study water resource issues on rangelands may be disappointed with the availability of ecological site information for their study area. Other vegetation classification systems are available, ranging from *ad hoc* classifications like Skirvin et al. (2008) on WGEW, or regional classifications like Southwest Regional GAP Analysis Project, or the National Vegetation Classification Standard. These other vegetation classifications have strengths, but they only describe the vegetation that currently exists, not potential alternative vegetation communities. Hence, these other classification systems also have fundamental limitations as ecological management tools.

Maps of ecological sites are available indirectly through SSURGO. For example, the SSURGO report for the area surrounding WGEW is an Order 3 soil survey (NRCS, 2003a) and is available online through the Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/), as are most soil surveys on rangelands. Order 3 surveys allow mapping units to contain several soil series, and each soil series could correspond to a different ecological site. Users need to be aware that soil map units can contain significant error when soil map units are assumed to contain only the ecological site of the dominant soil in the map unit. Desser (2008) found such an assumption could result in roughly a third of the area in the Tombstone Douglas Survey (AZ671) being in error due to inclusions and secondary soils in map units associated with other ecological sites. When using the Web Soil Survey the ecological sites for a mapping unit are available by defining the Area of Interest (AOI), selecting the Soil Data Explorer tab, and then the Ecological Site Assessment tab. In the table at the bottom of the page, the sites associated with each soil in the mapping unit are listed, but there is no way to know the precise location of individual sites within the mapping unit. For this reason NRCS Range Conservationists routinely make more detailed maps of ecological sites when performing conservation planning at the ranch scale.

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