Soil-landscape relationships and soil properties associated with rare plants in the eastern Mojave Desert near Las Vegas, Nevada, USA

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Abstract
The Upper Las Vegas Wash Conservation Transfer Area (ULVWCTA) provides habitat for two of Nevada's special status plant species, *Arctomecon californica* Torrey and Frémont (ARCCAL) and *Eriogonum corymbosum* Bentham var. *nilesii* Reveal (ERICOR). To aid the Bureau of Land Management Las Vegas Field Office in planning, we created a refined soil map focusing on soil-landscape relationships and characterized the soil properties associated with these plants of interest (POIs). We used a Geographic Information System (GIS), original SSURGO polygon lines, high-resolution aerial photography and digital terrain models, and Landsat and ASTER spectral data to refine the soil map. Forty-five soil pedons representing typical soil-landform-vegetation units were described, sampled, and analysed to help develop and document the refined map. We sampled and characterized 658 surface soils (0-8 cm) as part of a vegetation sampling of the ULVWCTA and a POI survey on the basin floor. POIs occur in map units on spring deposits and basin floor sediments that lack a thick gravel veneer: Las Vegas gravely fine sandy loam, 0 -2% slopes; and Badland. These $CaCO_3$-rich soils have petrocalcic horizons or carbonate nodules within 100 cm, and exhibited relict redoximorphic features, indicating they may be exhumed late-Pleistocene paleosols. Pedons in these units had <0.1-5.0% gypsum in the subsoil, but lacked gypsum in surface horizons. The first-to-third quartile ranges of surface pH, estimated clay%, bulk density, and calcified fragments ≥2-mm for POI points were 8.4-8.6, 12-16%, 0.84-1.06 Mg m^{-3}, 96-100%, respectively, and for shrub points were 8.2-8.4, 10-14%, 0.91-1.23 Mg m^{-3}, 0-70%, respectively. These data indicate the relatively narrow distribution of POIs on the basin floor compared to the wide distribution of shrubs on alluvial fans, the basin floor, and in drainage-ways. In the POI survey, surface soil properties differed little between the ARCCAL presence, ERICOR presence, and POI absence points on the basin floor. While it has been suggested that the POIs are gypsophiles, gypsum was rare in all surface soils. Geomorphic surface (e.g., spring deposit, basin floor) and soil map unit are better indicators of POI potential habitat than surface soil chemistry for supporting conservation, restoration, and urban planning efforts.

Key Words
No more than six key word items in order of decreasing relevance

Introduction

The Las Vegas Valley in southern Nevada is one of the fastest growing regions in the USA. The Bureau of Land Management (BLM) has been authorized to dispose of lands consistent with population growth and community land-use plans. The Upper Las Vegas Wash Conservation Transfer Area (ULVWCTA), on the north edge of Las Vegas Valley, provides habitat for two of Nevada's special status plants, *Arctomecon californica* Torrey and Frémont (ARCCAL) and *Eriogonum corymbosum* Bentham var. *nilesii* Reveal (ERICOR). These species are of special interest because they are uncommon and are thought to occur on very specific soil types high in gypsum (e.g., Myers, 1986). Additionally, ARCAL is in a plant family that is noted to have a variety of alkaloids, some of which are likely have medicinal value (Raynie *et al*., 1991).

Our objective was to create a refined soil map focusing on soil-geomorphic relationships and characterize the soils associated with these plants of interest (POIs). Our ultimate goal was to aid the BLM Las Vegas Field Office in conservation-based decision-making, ultimately helping land managers develop for implement plans for urban growth while minimizing impact to critical habitat for these rare, endemic plants**.**

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Methods

Study Area

The Las Vegas Valley is within the Mojave Desert Ecoregion of the Basin and Range physiographic province. This region is characterized by blocks of rock exhibiting high-angle normal faults translating into low angle detachment faults, forming mountain ranges surrounded by extensional basins filled with sediments eroded from the uplifted ranges. In the Upper Las Vegas Wash area, extensional spreading resulted in a northwest to southeast-trending shear zone, known as the Las Vegas Shear Zone (Page *et al*., 2005). Average annual precipitation in North Las Vegas is 12 cm and average annual temperature is 20°C with aridic and thermic soil temperature and moisture regimes, respectively.

During the Pleistocene epoch (about 1.8 mya to 10 kya), atmospheric precipitation was higher and air temperatures were cooler with reduced rates of evapotranspiration. The orographic precipitation produced in the mountains was significantly higher, manifested as groundwater discharge zones on the basin floor, resulting in spring, lake, and marsh deposits. These are rich in Pleistocene megafaunal fossils, including mammoth, camel, horse, bison, and antelope (Page *et al*., 2005).

The physiography of the ULVWCTA is characterized by broad, coalescing, and gently sloping alluvial fans (bajadas) emanating from mountains that descend to the nearly level basin floor. The basin floor is dissected by the Upper Las Vegas Wash. The parent material on alluvial fans is gravelly to sandy alluvium derived from sedimentary rocks, including limestone, dolostone, and chert. The basin floor comprises finer textured and highly calcareous lacustrine sediments and spring deposits, redistributed in some places by fluvial processes, and covered in some places by a veneer of gravelly to sandy alluvium. The parent material in the relatively active portions of the Upper Las Vegas Wash is gravelly to sandy to loamy recent alluvium.

Soil Map

We created a refined soil map for the ULVWCTA based on the most recently available (2007) SSURGO data for the soil surveys of the Las Vegas Valley Area, Nevada, Part of Clark County, NV 788; and the Clark County Area, Nevada, NV 755. We used Landsat 7 ETM+ (path 039 row 035; acquired June 4, 2000) bands 1-5 and 7, and ASTER (acquired September 19, 2004) bands 4-9 to gain understanding of general landscape patterns and help guide initial sampling. We used a Geographic Information System (GIS) and several digital data layers, including the high-resolution aerial photography (10-cm pixel) acquired September 2006 and the topographic contour map derived from the high-resolution digital terrain model to refine the soil map. We adjusted existing and drew new soil map unit polygon lines by interpreting tonal patterns and landform relief visible in high-resolution photography and topography (Figure 1A), distinguishing soil map units with greater spatial detail in the southeastern part of the ULVWCTA where POIs occurred.

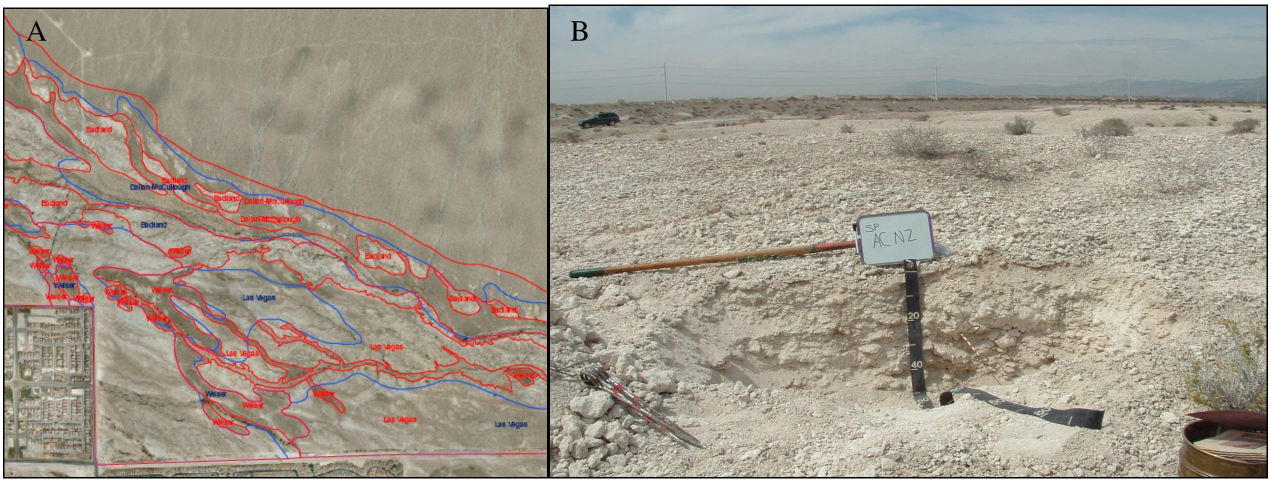

Figure 1. A) Soil map unit polygon lines were refined using high-resolution aerial photography and digital terrain models, after examination of remotely sensed spectral data. B) Typical soil habitat for the POIs.

Forty-five pedons representing typical soil and vegetation units were described, sampled, and analyzed to help develop and document the refined soil map. All pedons were exposed by manual excavation to ≥100-cm depth or to a physical root-restricting layer and described using standard National Cooperative Soil Survey methodology. Pedons were sampled by genetic horizon, and classified to family level using Soil Taxonomy and, where possible, correlated to the closest established soil series. The refined soil map used only existing map units in NV 788 and 755.

Surface soils

We sampled and characterized 658 surface soils (0-8 cm) as part of a general vegetation sampling throughout the study area and a POI survey on the basin floor. At each plot center, the surface soil was sampled under the canopy of the closest shrub (Shrub Presence), and 50-cm away from that shrub in the open (Shrub Absence). If POIs occurred within the 10-m radius plot, the surface soil next to or under the canopy of each plant of interest (ARCCAL or ERICOR Presence) and 50-cm away from that plant in the open (ARCCAL or ERICOR Absence) was also sampled. Surface soil samples from 0-8 cm were collected by pounding steel cylinders of known volume into the soil and excavating the core containing the soil. (If high rock fragment content prohibited us from extracting an intact core, the soil was sampled with a trowel to a depth of 8 cm and "No Data" was recorded for bulk density.) Surface soil samples were collected during the POI survey in the same manner as the vegetation sampling. For presence points we took a soil core sample next to or under the canopy of the plant of interest (ARCCAL or ERICOR Presence). For absence points soil core samples were taken in the open away from the rooting zone of all vegetation.

Laboratory Analysis

Bulk density was determined for soils sampled by intact cores. Soil samples were passed through a 2-mm sieve to separate rock and coarse fragments ≥2-mm. The percentage of calcified fragments in the ≥2-mm fraction was visually estimated. Texture class and clay% were estimated by feel. All subsequent laboratory analysis was performed on the <2-mm fraction: effervescence reaction, soil pH, electrical conductivity (EC) on a 1:2 soil: water suspension. Soil samples with EC >0.50 dS m^{-1} were selected for analysis for gypsum. Gypsum concentration was determined by dissolution in water and precipitation in acetone. Alkaline Earth carbonates (reported at $CaCO_3$) was determined on each genetic horizon for 11 typical pedons via manometric CO_2 evolution with HCl.

Results and Discussion

ARCCAL and ERICOR occur on map units typical of spring deposits and basin floor sediments that lack a thick surface veneer of extremely gravely alluvium, particularly 300-Las Vegas gravely fine sandy loam, 0 to 2 percent slopes (Figure 1B), and 630-Badland. These map units contain soils rich in finely disseminated calcium carbonate that have petrocalcic horizons, many carbonate nodules, and/or intermittent cementation by carbonates within 100 cm of the soil surface. Many of the soils we examined exhibited relict redoximorphic features, indicating they may be exhumed late-Pleistocene paleosols. All pedons sampled in these two map units had small (5%) to trace (<0.1%) amounts of gypsum in the subsoil, but all lacked gypsum in surface horizons. Soil where the POIs did not occur (SHRUB) were deep and gravely (Table1).

Surface soil pH, clay%, EC, bulk density, and percent calcified fragments ≥2-mm were similar between the presence and absence points for ARCCAL, ERICOR, and shrubs in the vegetation sampling (Table 2). However, the pH and percent calcified fragments ≥2-mm were higher and bulk density was lower in ARCCAL and ERICOR presence/absence points compared to shrub presence/absence sites. These data indicate the relatively narrow distribution of ARCCAL and ERICOR on the highly calcareous basin floor compared to the wide range of shrubs on alluvial fans, the basin floor, and drainage ways. There was little difference in the surface soil properties between the ARCCAL and ERICOR presence and absence points in the POI survey. While it had been reported elsewhere that ARCCAL and perhaps ERICOR are gypsophiles, reliably detectable amounts of gypsum were rare in all surface soils.

Conclusions

Previous work on these POIs focused on surface soils and few pedons within a narrow geographic zone (unpublished reports on studies funded by the BLM). Geomorphic surface (e.g., spring deposit, basin floor) and soil map unit may be better indicators of potential habitat to support conservation and restoration efforts than surface soil chemistry at individual sites. Understanding the geography and properties of soils that support these rare, endemic plants will facilitate planning for urban development while minimizing habitat loss and facilitate identification of habitat best suited for restoration efforts.

Table 1. Descriptive statistics of surface soil properties from the vegetation sampling. Only presence data are shown for ARCAL and SHRUB.

	pH	Clay	EC	Gypsum	Bulk Density	Calcified Fragments
		%	dS/m	%	Mg/m^3	%
			ARCCAL Presence			
N	*38*	*38*	*38*	*38*	*38*	*38*
Mean	8.5	15	0.37	0.0	0.96	92
St Dev	0.1	3	0.56	0.0	0.14	20
Median	8.5	15	0.22	0.0	0.95	100
1st Quartile	8.4	13	0.19	0.0	0.89	96
3rd Quartile	8.6	16	0.26	0.0	1.05	100
Minimum	8.1	8	0.15	0.0	0.64	0
Maximum	8.6	27	2.65	0.1	1.27	100
			SHRUB Presence			
N	*225*	*225*	*225*	*225*	*200*	*225*
Mean	8.3	12	0.30	0.0	1.07	27
St Dev	0.2	3	0.23	0.0	0.29	40
Median	8.3	12	0.24	0.0	1.10	0
1st Quartile	8.2	10	0.19	0.0	0.93	0
3rd Quartile	8.4	14	0.33	0.0	1.22	50
Minimum	7.7	5	0.10	0.0	0.44	0
Maximum	8.9	27	2.56	0.0	2.97	100

Table 2. Properties from representative pedons.

Horizon	Depth	pH	Clay	EC	Gypsum	$CaCO_3$
	cm		%	dS/m	%	%
SP-ACN2 (ARCAL and ERICOR present; Las Vegas series)						
A	0-9	8.4	22	0.19	0.00	47
Bkk	9-18	8.6	27	0.23	0.00	67
Bkkm1	18-31	8.5	-	1.29	0.00	67
Bkkm2	31-48	8.3	-	1.68	0.00	69
Bkkm3	48-54	8.5	-	-	-	58
SP-0303 (POI Absent; Weiser series)						
A	0-8	8.4	15	0.22	0.00	40
Bk1	8-17	8.5	14	0.17	0.00	44
Bk2	17-44	8.5	13	0.14	0.00	48
Bkq1	44-71	8.5	12	0.12	0.00	48
Bkq2	71-94	8.6	12	0.12	0.00	52
Bkq3	94-114	8.5	12	0.14	0.00	50

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