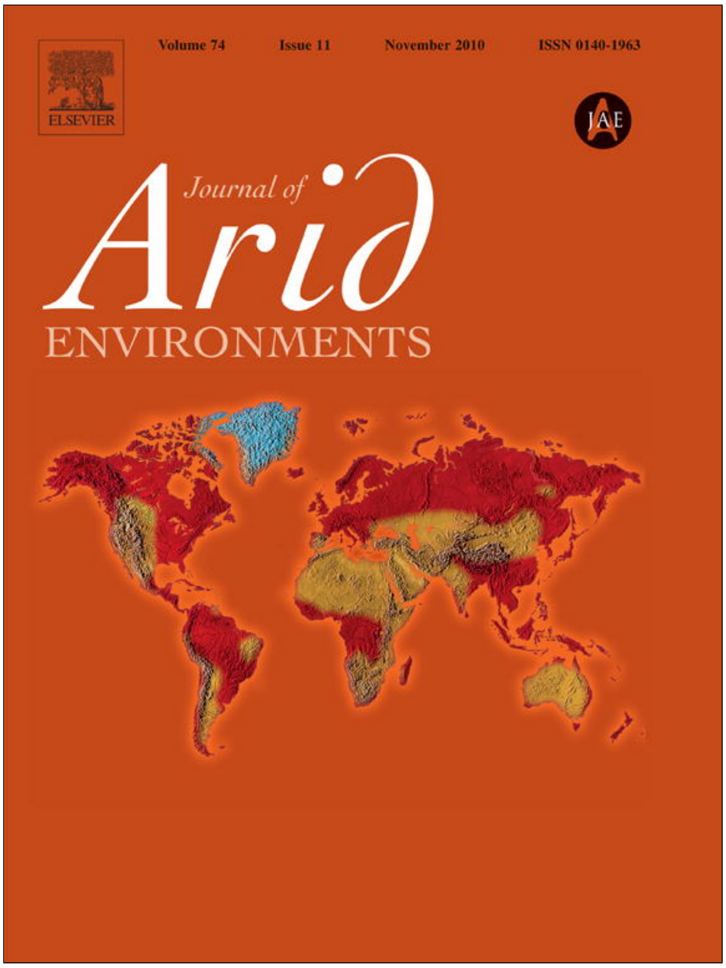
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Use of terrain attributes as a tool to explore the interaction of vertic soils and surface hydrology in South Texas playa wetland systems

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ABSTRACT

The objectives of this study were to assess the unique interface between geomorphology, hydric soils, surface hydrology, and plant ecology in playa landforms by: 1) characterizing playa soil properties; 2) quantifying playa microtopography; and 3) determine how watershed attributes dictate the potential for surface water accumulation following episodic precipitation events (tropical storms, hurricanes). Soils of 9 playa basins in the Rio Grande Plains of Texas, USA were analyzed for physical/chemical properties and their microtopography determined via transects. A DEM was used to calculate topographic wetness index (TWI) and evaluate the sizes of playa basins, the upland draining areas into each playa. There were no significant differences among playa soils. TWI showed the potential areas for surface water accumulation coinciding with playa location. TWI can be used as a tool to identify potential water accumulating areas. The soil, site characteristics, and weather conditions determine the duration of standing surface water.

1. Introduction

Playas are broadly defined as the lowest portions of closed-basins, which are intermittently or seasonally inundated (Jackson, 1997 and Brostoff et al., 2001). These landforms, described as “self-contained within their own watershed”, are dependent on precipitation or run-off from surrounding uplands for surface water; and playas of the Great Plains are not typically recharged from rising groundwater (Smith, 2003). Playas can become ephemeral lakes upon inundation and may support freshwater vegetation and other aquatic lifeforms. As such, playa landforms encompass unique interfaces between geology, hydrology, and plant ecology (Bolen et al., 1989). They have been attractive research subjects worldwide because they are valuable sources for aquifer recharge, agricultural irrigation, and avian, mammalian, invertebrate, and plant biodiversity in otherwise arid ecosystems. Although playas or playa-like landforms occur extensively in the Rio Grande Plains of Texas and Mexico, there is little known of their ecology, The playa landforms in this region are unique in comparison to those of the Great Plains and southwestern deserts in that their vegetation structure is highly variable, ranging from grassland to open savanna to closed savanna or even woodland (Farley, 2000). This study represents a first step in determining the underlying causes for this broad range of physiognomic diversity.

Stratified sediment layers in playa basins may result from soil deposition accompanying rainfall run-off from surrounding uplands (Brostoff et al., 2001) or from eolian deposition (Pelletier and Cook, 2005) and can influence the structure and fertility of playa soils. Run-on received from uplands supplements precipitation inputs and can frequently lead to an accumulation of water in the playa basin that may take days to months to infiltrate, percolate or evaporate (Blodgett et al., 1990; Dinehart and McPherson, 1998; and Neal and Motts, 1967). In settings where evaporation predominates over infiltration salts may accumulate in soils over time; and when inundation periods are prolonged, anaerobic conditions may prevail in plant rooting zones. Both of these may influence the composition and pattern of vegetation (Sanderson et al., 2008) and may be at play in determining the relative abundance of grasses, shrubs and arborescents in playas of the Rio Grande Plains.

Agency directives, legislation, and initiatives from non-governmental organizations have been recently established to promote conservation efforts on playa ecosystems (Smith, 2003). For

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example, in August 2004 the United States Department of Agriculture (USDA) announced a Wetlands Restoration Initiative of the Conservation Resource Program (CRP) under the Farm Bill. This initiative marks the first time that the USDA has defined playa lakes and calls for their protection by allocating 22,660 ha for enrollment starting October 1, 2004. Once enrolled in the Wetland Reserve Program (WRP), playas would be protected in perpetuity. With the advent of such programs, there is an emerging need to improve out scientific understanding of these unique ecosystems beyond the traditional emphasis on agriculture and wildlife and broaden our understanding of how soils, topography, and surface hydrology interact to influence vegetation composition, productivity and dynamics. Without quantitative information pertaining to these fundamental ecological features, it will be difficult to develop and prioritize progressive and effective monitoring, management and conservation plans (Bolen et al., 1989; Haukos and Smith, 1994; Smith, 2003). In working toward the goal of developing an ecohydrological perspective (Newman et al., 2006) on the diverse and contrasting vegetation structure of playas in the Rio Grande Plains Biotic Province, we sought to: 1) characterize their soil physical/chemical properties; 2) describe their basin morphology and microtopography; 3) utilize a digital elevation model (DEM) and geographical information system (GIS) to determine the potential for surrounding lands to contribute to surface water accumulation; and 4) document the extent and magnitude of surface water accumulation following an episodic rainfall event (Hurricane Bret).We then use this data to test the hypothesis that the dramatic differences in playa physiognomy are the result of differences: (1) in soil physical/chemical properties; (2 in basin depth; and (3) in the area of upland that drains into the playa basin.

2. Materials and methods

2.1. Study Site

Field research was conducted at the Texas AgriLife La Copita Research Area (LCRA) in the eastern Rio Grande Plains, Jim Wells County, Texas (27°40′N; 98° 12′W), about 64 km west of Corpus Christi. Climate of the area is subtropical with hot summers and mild winters. Mean annual temperature is 22.4 °C, with an average temperature of 14 °C in January and 29 °C in August. Mean annual precipitation is 680 mm, with 70% of rainfall occurring between April and September (Scifres and Koerth, 1987). Precipitation events that occur in the autumn are often associated with tropical storms (USDA, 1979), which serve to inflate the mean annual rainfall value.

Landscapes on the LCRA consist of sandy loam uplands, which grade (1–3% slopes) into clay loam intermittent drainage-woodlands. The vegetation of uplands is savanna parkland consisting of discrete clusters of woody vegetation embedded within a matrix of C_4 grasses, while drainage-woodlands are characterized nearly continuous cover of woody plant canopies (Fig. 1). Honey mesquite (*Prosopis glandulosa* var. *glandulosa*) dominates the overstory in both the uplands and lowlands, with numerous (10–15) species of shrubs occurring beneath its canopy (Archer, 1995 and Blair, 1950).

There are 26 soil series mapped in Jim Wells County and 14 of those occur on the LCRA (Fig. 1) (USDA, 1979). These soils are in the hyperthermic temperature regime and are represented by two orders (9 Mollisols and 5 Alfisols) and 5 great groups (Argiustolls, Paleustalfs, Paleustolls, Argiustolls and Halplaquolls). Soils in the uplands are in the ustic moisture regime, and characterized by mixed, fine-loamy, loamy and loamy-skeletal family particle size classes and contain an argillic horizon (and sometimes a petrocalcic horizon) within 40 cm of the surface (Loomis, 1989).

Playa-like landforms at the LCRA site are closed-basin depressions situated in intermittent drainage ways and are typically surrounded by woodlands with dense shrub thickets (Fig. 1). These landforms, mapped as having an aquic moisture regime, exhibit relatively similar characteristics described in the geomorphic definition of "playa" (Gustavson et al., 1995) and will be referred to as such throughout the remainder of this paper. There were substantial differences in the vegetation structure among playas at La Copita. Some were grass-dominated with no woody plants, some were grass-dominated with scattered, large woody plants (total woody plant basal area 9–36 m^2/ha), and some were dominated by a nearly continuous canopy of arborescents with a minimal grass layer (woody plant basal area > 70 m^2/ha). Playa vegetation physiognomy thus ranged from grassland (treeless) to open savanna to woodland. When trees were present, honey mesquite or *Huisache* (*Acacia smallii*) were typically dominant or co-dominant. Three woody species at the LCRA are largely confined to playas (*A. smallii*, *Sesbania dnimondii*, and *Parkinsonia aculeate*; Farley, 2000) which comprise about 1% of the LCRA land cover (Scifres and Koerth, 1987). Playas that had been disturbed by pipeline and ranch road developments were excluded from consideration. Twelve playas were identified as part of a larger project; and were assigned unique site numbers. Eight of these playas were sampled for this research project (1,2,3,4,5,6,7, and 9).

2.2. Soil sampling

Soil sampling was conducted in playas 1, 3, 4, 5, 6, and 7 during the 1998–1999 field seasons. Three pairs of cores (5 cm diameter × 150 cm length) were collected at random in tree intercanopy zones, divided into 10-cm increments, placed in labeled bags and stored at room temperature. Hand-texture, structure, Munsell color, and redoxomorphic features of each segment was subsequently described according to standard procedures (Soil Survey Staff, 1993). Physical features were then used to assign horizon boundaries to the nearest 10 cm. Particle size distribution (Kilmer and Alexander, 1949), soil reaction (pH), bulk density (oven dry and field), and salinity/electrical conductivity was conducted at the Texas A&M University Soil Characterization Laboratory using standard Soil Survey Staff (1996) protocol.

2.3. Basin surface microtopography

Surface topography within Playas 2 and 3 was quantified using a transit/level unit (Keuffel and Esser Paragon) with 2 cm accuracy. In Playa 2, a grid was established by first extending a meter tape the width of the playa, creating an *X*-axis. Another meter tape was placed perpendicular at the 0-m mark, denoting a *Y*-axis. Elevation within the grid was recorded at 2–3-m intervals (depending on the visibility of the Philadelphia Rod) relative to a fixed point at the margin of the woodland community defining the playa border. A GPS unit with 1 m horizontal accuracy was utilized to register locations of the grid corners. Owing to time and logistical constraints, surface elevation readings in Playa 3 were directed to areas where topological changes were visually evident.

2.4. Topographic wetness index

Water accumulation following rainfall events should be related to the size and depth of the playa basin and the amount of run-off flowing in from the surrounding landscape components. The USGS 10 m digital elevation model (DEM) was used to quantify the sizes of playa basins, to estimate the area draining into them and to generate topographic wetness index (TWI) values defined as:

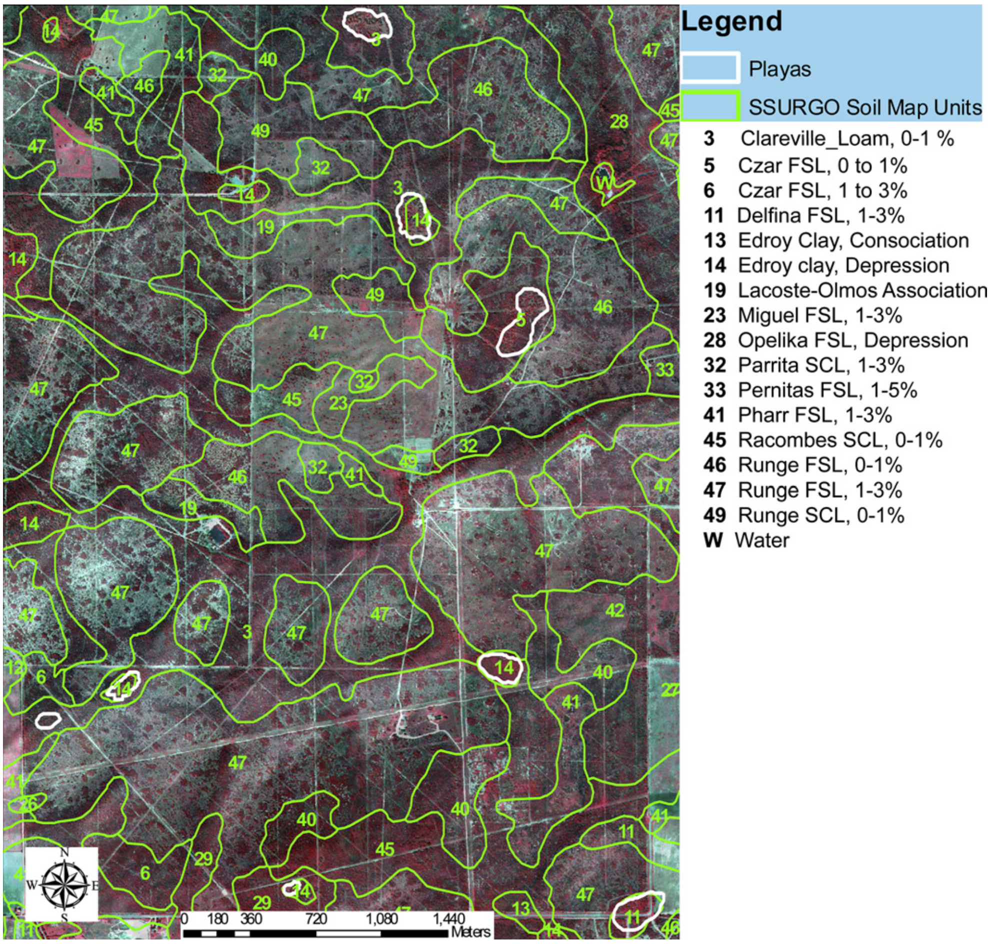

Fig. 1. Aerial color infrared image (USDA-FSA-APFO NAIP MrSID Mosaic, 2004) of the La Copita Research Area in the Rio Grande Plains of southern Texas overlain with SSURGO soil series map and showing the location of 7 playas (outlined in white).

$$TWI = \ln\left(\frac{\alpha}{\tan\beta}\right) \tag{1}$$

where α = the upslope area (m^2) per unit contour length contributing flow to a pixel; and β = slope angle (radians) acting on a cell (Quinn et al., 1995).

The TWI was used to represent the potential moisture status of given location or cell, as is determined by the accumulative upslope area draining into the cell and the slope inclination within of the cell. TWI values valid only when there are soil horizons limiting the percolation of water. USDA-Natural Resources Conservation Service (NRCS)-Soil Survey (Fig. 1), indicate subsoil conductivities on the LCRA range from 0.01 to 1 μm s^{-1} which would constitute hydrologic limitation to vertical water movement. Watersheds containing playas were gridded into 10 × 10 m cells and the slope and the accumulative upslope area draining into the cell ("flow accumulation", Jensen and Dominque, 1988) was estimated based using SAGA (System for Automated Geoscientific Analyses) (http://www.saga-gis.org/) (Bock et al., 2007). A SAGA-generated TWI was preferred as it allowed for the adjustment of the input T value, which controls the width and convergence of the flow path (Holmgren, 1994).

2.5. Surface water accumulation

On August 22, 1999, the eye of Hurricane Bret passed approximately 48 km south of the LCRA and produced heavy rainfall and localized flooding in the region (NOAA, 1999). Rainfall recorded at LCRA rain gauges was spatially variable, ranging from 14 to 25 cm. To quantify the effects of this large, episodic rainfall event on soils and surface hydrology transects were established along the long axis and perpendicular to the long axis in basins with standing surface water (Playas 1, 3, 6, and 9) and water depths (cm) was measured at 1 m intervals. The perimeter of standing water and the transect locations were then recorded using a GPS with 1-m horizontal accuracy. All measurements were made 14 days after the storm. The GPS outline of standing surface water was overlain on a georeferenced aerial photo (1:40,000) to spatially represent where ponding occurred in the basins. As a test for anaerobic conditions in soils, as indicated by the presence of reduced iron, an α,α-dipyridyl solution was applied (5–10 drops) to soil samples (Childs, 1981). Soils were extracted using a sharpshooter shovel (from 0 to 50 cm) and a hand auger to examine deeper soils (50–75 cm).

2.6. Statistical analysis

Statistical analyses were conducted using Statistical Analysis System (SAS, 1996). One-way ANOVA was used to compare the soil properties at a given depth and TWI values between playas. Playa was treated as class variable and measured soil properties and TWI values as a continuous random variable. Significant differences among means (α = 0.05) were determined using *Tukey's W* procedure. Proc-REG was used to quantify the relationship between TWI values and playa area.

3. Results and discussions

3.1. Playa soils characteristics

Playas on the LCRA, like those in the Southern High Plains are characterized by soils classified as Vertisols and vertic integrades (USDA, 1979). The orders within LCRA playas were Mollisols and Vertisols with Vertic Argiaquolls and Ustic Epiaquerts subgroups, respectively (Table 1). The Vertic Mollisols did not qualify as Vertisols, because they either did not contain ≥ 30% clay to the surface or because they lacked slickensides within the upper meter of the soil profile (Soil Survey Staff, 1998).

Soils were grouped into similar taxonomic classifications for comparisons. Although the soils within playas were classified into different taxonomic orders, both subgroups generally exhibited similar physical and chemical characteristics with depth (Table 2). The soil surface horizons were dark (10YR 2/1) with angular blocky structure and clay/clay loam texture. Generally, the B-horizons were comparably dark in the upper 30 cm (10YR 2/1) and bocaming lighter in color (10YR 4-6/1-2) at 100 cm. The soils within the playa all had clay textures to a depth of 60–100 cm. The subsurface horizons within the playa had distinct morphological characteristics including clay films, pressure faces, and soft calcium carbonate masses. Redoximorphic features including iron depletions, clay depletions, iron concentrations, and Fe–Mn nodules were also observed in the subsurface horizons. The presence of redoximorphic features is an indication that the soils within the playas have undergone saturated and reducing conditions. Although masses of $CaCO_3$ were sometimes present in the lower 50 cm, no petrocalcic horizons were identified. The C-horizons had a decrease in clay and typically had weak prismatic structures. Soils at the interface of the playa-drainage woodland boundary had fine sandy loam and sandy clay loam textures in the surface; and clay loam, sandy clay loam and loam subsurface textures.

The overall mean oven dry bulk density of the playa soils (1.8 ± 0.03 g/cm^3) was comparable to that which has been reported for other Texas Vertisols (Wilding, 1999). The slight difference in oven dry bulk density and field bulk density probably reflects the fact that soils were extremely hard and dry at the time samples were taken. Since the samples were collected prior to Hurricane Bret and during a dry period, the water content at the time of sampling, pooled across all depths ranged from 4.2 to 6.4% (Table 1), with the clayey B-horizons retaining the most moisture (Ustic Epiaquert = 5.6%, Vertic Argiaquoll = 6.4%).

Soil properties at a given depth were generally statistically comparable across the playas. Noteworthy exceptions include clay content in the B-horizon (30–100 cm), EC in the 0–30 cm depth, and pH in the B–C transitions and C-horizons (100–150 cm) (Table 2).

3.2. Basin microtopography

The playas at La Copita are relatively oval shaped (Fig. 1) and range in size from 0.1 to 3.8 ha (Table 3). The percent change in elevation did not show any trend with playa size; however, playas with larger upslope contributing areas tended to have larger percent differences in elevation. The watershed area draining into the playa basins ranged from 11.64 to 88.10 ha (Table 3). Field observations indicated that there was variation in microtopography within individual playas was not accounted for given the coarse scale of the DEM. The lower areas of a playa can retain standing water in an otherwise dry basin. For instance, only the lower areas of Playas 3 and 6 retained surface water five weeks after Hurricane Bret. Moreover, the slight differences in microtopography in the DEM were not portrayed due to a lack of a sufficient amount of GPS sampling points.

3.3. Topographic wetness index and surface water accumulation

The TWI values for 10×10 m pixels on LCRA ranged from 8 to 16, with TWI values for pixels within playa basins all being consistently in the higher end (TWI = 13–16) of this range (Fig. 2). The mean TWI value for playas (14.2) was thus greater than that for the LCRA as a whole (12.4), indicative of their occurrence in topographic lows. Contrary to expectations, TWI values did not vary significantly between playas (Fig. 3). There was, however, a significant negative correlation ($R^2 = 0.8$; $p < 0.01$) between playa size versus difference between maximum and minimum TWI values within a basin (Fig. 4) which indicates that smaller playas with large contributing areas tend to accumulate more surface water. TWI values indicated all playas on the LCRA could potentially accumulate surface water (Fig. 3). However, TWI values did not concur with the field data collected on water depth measured after Hurricane Bret. For instance, Site 6, which had the lowest TWI value (12.6; Fig. 3) retained standing water even in relatively shallow portions of its basin, whereas Site 5, with the third highest TWI ranking (14.2) contained no surface water on the measurement date. The extent and depth of standing water present 14 days after Hurricane Bret varied substantially between playas. Playa 9 was very symmetrical with respect to its depth, had the deepest recorded depth (38 cm) of all playas (Fig. 4); and surface water was present throughout its basin when the site was observed six weeks after Hurricane Bret. By contrast, playas 1, 3 and 6 were shallower and relatively asymmetrical with respect to depths within their basins. Five weeks after Hurricane Bret, standing water was present only in the deepest areas of the basins. Anaerobic conditions (as indicated by a positive α,α-dipyridyl reaction) to a depth of 10 cm occurred at distances of 0.5 m–2.5 m from pool margins for basins with standing surface water. Surface water was not present in Playas 4 and 5 on the 14th day post-Brett, but their soils tested positive for anaerobic conditions.

Several factors related to DEM resolution, microtopographic variation, field measurements density, local disturbances, soil characteristics and weather conditions may account for the discrepancies between the TWI predictions and the presence of surface water in playa basins after Hurricane Bret. First, TWIs are often used for landscape analysis on larger scales such as

Table 1
Mean ± SE physical characteristics and chemical properties of playa soils with depth (0–30 cm; 30–100 cm; 100–150 cm) in the Rio Grande Plains, Texas, USA. The physical and chemical properties were not significantly different between soil orders.

Sites	Order	Subgroup	Horizon	Depth	Texture*	% Clay	pH	EC (dS/m)	Oven Dry Bulk Density (g/cm3)	Field Bulk Density (g/cm3)	% Water
1, 3, 4	Vert.	Ustic Epiaquert	A1/A2	0–30	cl, c	40.5 ± 0.8	6.5 ± 0.1	0.231 ± 0.03	1.77 ± 0.02	1.75 ± 0.01	5.3
2, 5, 6, 7	Moll.	Vertic Argiaquoll	A1/A2	0–30	cl, c, sc	30.4 ± 1.1	6.5 ± 0.1	0.350 ± 0.05	1.82 ± 0.04	1.83 ± 0.04	5.9
1, 3, 4	Vert.	Ustic Epiaquert	Btss	30–100	c	41.6 ± 0.5	7.0 ± 0.1	0.236 ± 0.02	1.73 ± 0.01	1.73 ± 0.02	5.6
2, 5, 6, 7	Moll.	Vertic Argiaquoll	Bt	30–100	c	38.2 ± 0.9	7.0 ± 0.1	0.442 ± 0.08	1.78 ± 0.03	1.76 ± 0.03	6.4
1, 3, 4	Vert.	Ustic Epiaquert	BC	100–150	cl, c	35.4 ± 2.3	7.2 ± 0.1	0.330 ± 0.02	1.75 ± 0.02	1.75 ± 0.02	4.2
2, 5, 6, 7	Moll.	Vertic Argiaquoll	BC	100–150	c, cl	39.5 ± 0.8	7.5 ± 0.1	0.470 ± 0.08	1.72 ± 0.02	1.72 ± 0.02	6.0

*cl = clay loam, c = clay, sc = sandy clay.

Table 2
Results from one-way ANOVA of soil physical and chemical properties at a given depth across all playas.

Depth (cm)	% Clay		pH		EC (dS/m)		Oven Dry Bulk Density (g/cm3)		Field Bulk Density (g/cm3)	
	F-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value
0–30	0.23	0.640	0.02	0.899	4.62	0.050	1.03	0.331	4.06	0.100
30–100	11.42	0.006	0.02	0.899	2.58	0.133	2.17	0.164	1.12	0.311
100–150	2.45	0.152	7.88	0.004	2.09	0.156	0.33	0.581	1.00	0.351

F-value is the test statistics used for comparing mean values. *p*-value is the level of significance. Results were significant at $p \leq 0.05$.

mountainous terrain with high relief; thus, the 1:24,000 USGS topography map used for the DEM scale may have been too coarse (Del Barrio et al., 1997) to capture important microtopographic variation within playas at the scales illustrated in Fig. 5. In landscapes characterized by subtle topographic features, such as those on the LCRA, higher densities of elevation measurements than those available for this study would help resolve some of these issues. Second, our field measurements of standing water were not made until 14 days after Hurricane Bret. Patterns of water accumulation may have changed substantively by this time owing to percolation and evapotranspiration. Third, the TWI also does not account for disturbances that may alter the magnitude and direction of surface water flow (Winter et al., 1998). Sites 1 and 6 were situated near main roads and had also been recently roller chopped (Farley, 2000), a common brush management practice on ranches in the region. It is possible, that flows along these disturbance paths may have augmented surface water inputs into playas. Fourthly, once a basin fills, additional water would spill onto the intermittent drainage and be transferred downslope; and this would be most likely to happen on sites where playa basins are shallow and the elevation difference between the playa margin and the intermittent drainage is small (Fig. 2). In these cases, levels of standing water in playa basins would not truly reflect the amount of water delivered to the basin. So, if the TWI approach is to be a useful tool for predicting areas of potential surface water accumulation these issues need to be addressed.

Soil characteristics, which are not included as a parameter in the digital model, are presumably the correlating determinant of surface water accumulation. It is important to consider the environmental conditions of the Rio Grande Plains prior to and after Hurricane Bret in order to draw reasonable inferences from standing surface water data. Playa soils were hard and extremely dry prior to the Hurricane, as indicated by the extremely low water percentages (4.2–6.4%; Table 1). Soils within the playas were observed and basin surfaces contained prominent cracks (Farley, 2000). Coulumbe et al., (1996) found that high clay soils may have high initial rates of infiltration due to open cracks. Also the angular-shaped peds of vertic soils often do not become aligned during swelling; and the air space between the peds provides a passage for further water percolation. Even under saturated conditions, vertic soils may have hydraulic conductivity rates as high as 2.5 cm/day (Coulumbe et al., 1996). Thus, it is possible that over 25 cm of retained water could have percolated in the subsoil in less than two weeks leaving little or no standing water in the playas. In the soil morphologic field descriptions and soil laboratory analysis, surface textures for playas 1,3,6 and 9 all had clay textures with over 40% clay; whereas playas 2,4, 5, 7, and 8 had sandy loam, sandy clay loam and clay loam textures in the surface horizons. This difference in clay content could account for the differences in standing water. Loamy soils have higher infiltration and hydraulic conductivities and may provide a mechanism for surface water to be absorbed into the soil. When the playa soils with clay textures become saturated, the clay particles, which are dominantly smectitic (Loomis, 1989), may swell and seal the surface (Wilding and

Table 3
Size of playa basins (ha); upslope contributing area draining into playa (ha); and percent difference between maximum and minimum TWI and Elevation values calculated from a DEM of the La Copita Research Area.

Playa Site	Playa Area (ha)	Upslope Area Draining into Playa (ha)	Difference (%)	
			Wetness Index	Elevation
1	2.0	11.6	10.3	0.29
2	0.6	20.8	12.6	0.95
3	1.0	26.1	13.7	1.04
4	3.2	53.2	10.3	0.85
5	2.8	33.8	9.2	0.82
6	2.6	16.6	10.7	1.08
7	3.8	77.9	8.4	0.61
9	0.1	88.1	0.1	0.01

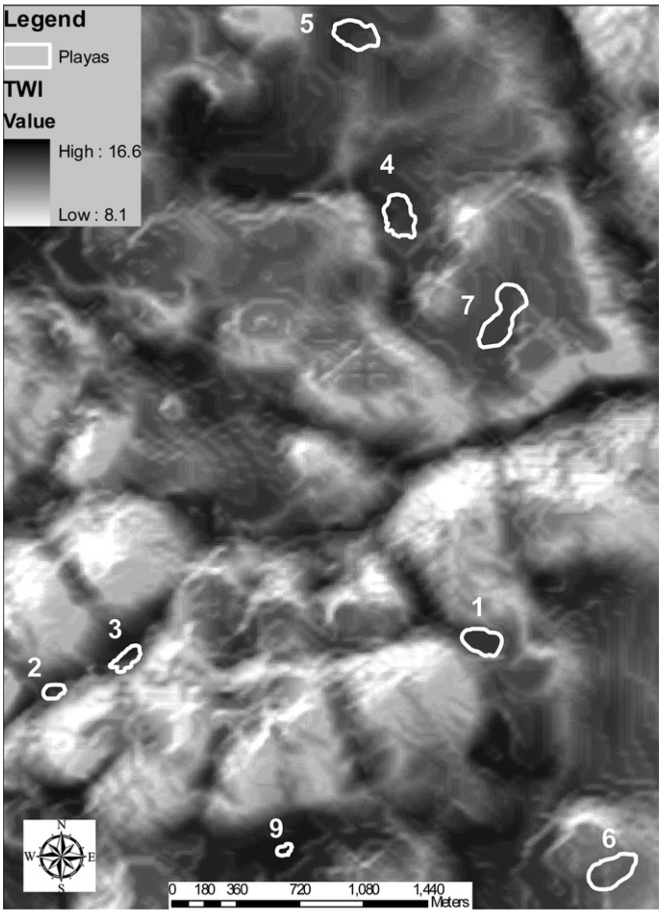

Fig. 2. Spatial distribution of Topographic Wetness Index values on the La Copita Research Area with the location of the 7 playa landforms used in this study outlined in white (note: playa numbers are IDs generated from larger study that included more playas than are shown here).

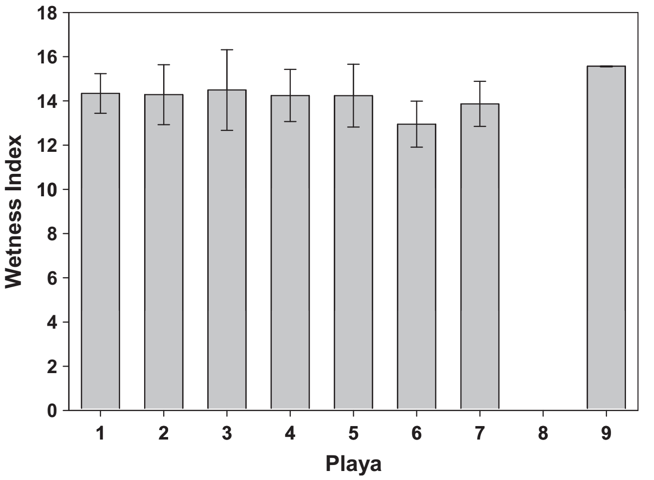

Fig. 3. Mean Topographic Wetness Index for 7 playas on the La Copita Research Area study site. Note: playa numbers are IDs generated from larger study that included more playas than are shown here.

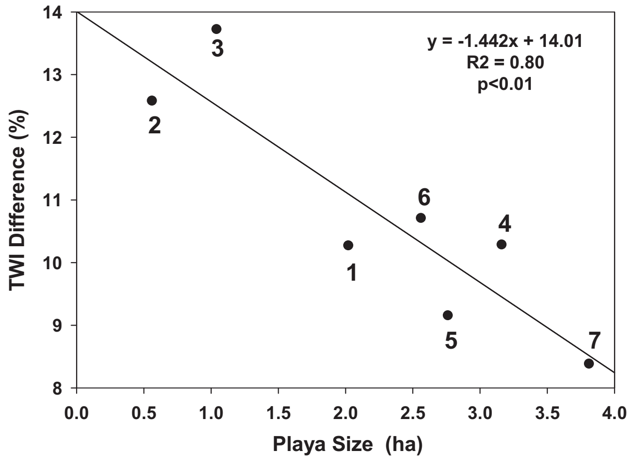

Fig. 5. Microtopography and water depth (cm) in four playa basins on the La Copita study site August 28, 1999, 14 days after Hurricane Bret delivered?? mm of precipitation. Anaerobic conditions in soils (α,α-dipyridyl test) at waters edge (denoted by *) were observed in each of the playas. Playa 4,5, and 7 had no standing surface water on this date, hence are not shown. Playa 3 had two distinct two distinct areas of water accumulation that were inventoried separately (Pools A and B).

Puentes, 1988). There is not enough conclusive data to explain the observed differences in surface water accumulation between the playas. More research is needed to determine the interaction between surface hydrology, vegetation and soil differences amongst the playas. In addition, evaporation rates following Hurricane Bret averaged 0.86 cm per week for August (NOAA, 1999), accounting for some of the water loss. Information on transpiration rates during this period is not available. However, the playas and the woodland communities surrounding them are characterized by dense, productive plant communities; and shrubs and grasses in these communities were observed to initiate new growth in the days and weeks following the hurricane, suggesting transpiration rates could likely have been high. Also, since data collection was performed only after Hurricane Bret, all conclusions must be made in the context of this one precipitation event. Jim Wells County received only 2.03 cm of rainfall in July 1999 and no rainfall in August until Hurricane Bret (NOAA, 1999; LCRA Weather Station).

3.4. Observations and implications for hydric soils

In general, smaller deeper playas contained more standing water after Hurricane Bret; whereas, the larger shallower playas either contained no standing water or just in isolated depressions. Soils in playas lacking ponded water had a negative reaction with α,α-dipyridyl inferring aerobic conditions, whereas soils adjacent to playas with ponded water had a positive reaction, indicating reduced iron (Fe^{2+}) that occurred from 0 to 15 cm. From 15 to 75 cm there were no positive reactions to α,α-dipyridyl indicating these soils exhibited episaturated conditions. The field morphological features in playa soils that contained ponded water did not correlate with the observed reducing soil. For all playa soils, the soil matrix color was black (10YR 2/1) and there were light brownish gray (10YR 4-6/2) iron depletions that occurred ≥30 cm. According to the Federal Register (1994), soils formed under conditions of saturation, flooding or ponding long enough during the growing

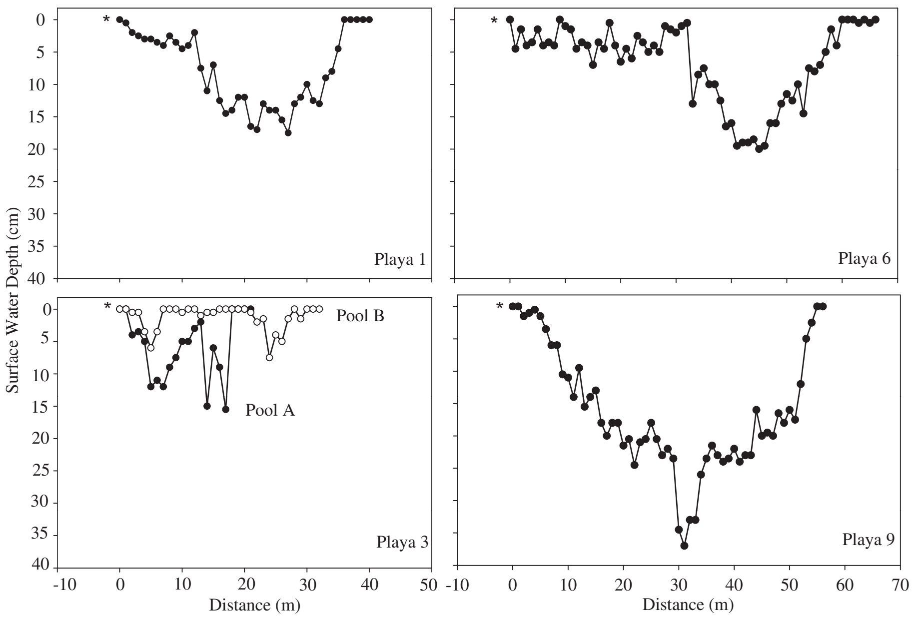

Fig. 4. Difference (%) between maximum and minimum Topographic Wetness Index values in 10 × 10 m pixels within playas as a function of playa area (m^2) at the La Copita site.

season to develop anaerobic conditions in the upper part would be characterized as hydric soils. The ponded soils in some of the playas met the requirements of hydric soils during this one observation following Hurricane Bret; however, the morphological features did not indicate reducing conditions in the upper part. Playas in the arid southwestern part of the United States exhibit similar characteristics (Brostoff et al., 2001). Soils were found to exhibit redoximorphic features in the lower part of the pedon and lack features in the upper part. The data from this research regarding evidence of hydric soil function coincides with Brostoff et al. (2001) who concluded that playa soils often lack iron segregations in the upper horizons. Since the evidence for playa soils lack the common hydric soil indicators commonly found in more humid environments (Federal Register, 1994), other parameters such as accumulation of organic matter, salt crystals, soil structure and texture should be used to delineate hydric soils.

4. Conclusions

Playas in the Rio Grande Plain are unique and provide many potential benefits for this semi-arid ecosystem due to their potential to accumulate water during high rainfall events. Hurricane Bret passed near the playas of the study site in 1999 and provided an ideal field situation in which to study how playas react to a single significant rainfall event. The presence of ponded water in the playas following this hurricane event provided insight into the variations of surface water accumulation and duration. Four playas contained standing water following the hurricane, while five playas did not. When compared to the predicted surface water accumulation using the TWI, there was not a strong correlation between observed surface water accumulation and the average TWI values. For instance, two of the playas that retained standing surface water (Playas 1 and 6) did not receive highest TWI rankings. On the other hand, two of the dry playas (Playas 4 and 5) observed after Hurricane Bret had higher TWI values. The two weeks delay in measuring the surface water accumulation may have been one of the major contributors in enhancing the discrepancies with TWI values due to weather conditions. Improved resolution of digital elevation models (DEM) would greatly enhance the ability to predict potential surface water accumulation within the playas. Quantifying the landscape topography with a DEM alone cannot fully characterize the potential for playas to accumulate water without understanding playa soil properties.

The soils in the playas of the Rio Grande plains consisted of Vertic Argiaquolls and Ustic Epiaquerts. In the soil morphologic field descriptions and soil laboratory analysis, surface textures for playas 1,3,6 and 9 all had clay textures with over 40% clay; whereas playas 2,4, 5, 7, and 8 had sandy loam, sandy clay loam and clay loam textures in the surface horizons. This difference in clay content could account for the differences in standing water. Loamy soils have higher infiltration and hydraulic conductivities and may provide a mechanism for surface water to be absorbed into the soil.

The interaction between the hydrology and soils of the Rio Grande Plain playas systems are important for understanding the ecosystem functions. These systems support different vegetation, wildlife habitats, and potentially provide groundwater recharge. These ecosystems may be protected through laws regulating wetlands. The field evaluations of the soil morphology indicated that these soils did not express morphological features associated with hydric soils. However, following Hurricane Bret the playa soils and soils adjacent to playas had ponded water and a positive reaction with α,α-dipyridyl indicating reduced soil conditions. The field observations and measurements indicate that some playa soils would meet the hydric soil definition and allow for these systems to be potentially federally protected.

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