Journal of Arid Environments 74 (2010) 1487–1493

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

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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A R T I C L E I N F O

Article history:
Received 28 January 2009
Received in revised form
22 February 2010
Accepted 8 June 2010
Available online 31 July 2010

Keywords:
Playa
Arid environment
Hydric soils
Surface hydrology
Seasonal wetland
Topographic wetness index

A B S T R A C T

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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0140-1963/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jaridenv.2010.06.006

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: