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Soil property variation within an aridisol in Big Bend National Park, Texas, USA

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ABSTRACT

The ecological and edaphic characteristics that dictate the existence and extent of typical vegetation cover types on Tornillo loam (Ustifluventic Haplocambid), a soil common to the northern Chihuahuan Desert region within the boundaries of Big Bend National Park (BBNP) and prone to erosion, are not well-known. The objective of this study was to evaluate near-surface soil physical and chemical properties as potential explanatory characteristics for different patchy vegetation types [i.e., bare soil, creosote (*Larrea tridentate*) flat, and grass] on Tornillo loam in the northern Chihuahuan Desert region of BBNP in southwest Texas. Results showed that soil bulk density in the top 5 cm and penetration resistance in the top 20 cm were similar ($P > 0.05$) among all three vegetation cover types, but soil particle-size distributions in the top 20 cm differed significantly ($P < 0.05$). Extractable soil Na and soil pH in the top 6 cm were both greater ($P < 0.05$) in the bare-soil areas (482 mg kg^{-1} and 8.9, respectively) than in the grass patches or creosote flats, which did not differ (115 mg kg^{-1} and 8.5, respectively). Future research should further investigate interactions between near-surface soil chemical characteristics, particularly soil Na concentration and pH, and past and future restoration activities to promote revegetation and control erosion.

1. Introduction

The Chihuahuan Desert is the largest desert in North America (NMSU, 2014) covering an estimated area of over 80.9 million ha (NPS, 2014). More than 80% of the Chihuahuan Desert occurs in several northern and north-central states of Mexico, with the northern-most extent reaching into southeastern Arizona, southern New Mexico, and southwest Texas (CDNC, 2014). However, in many places, the northern Chihuahuan Desert has experienced somewhat severe ecological transformations since the mid-1800s (Johnson et al., 2000; Perkins et al., 2006), mainly in the form of shifting vegetation types from desertification (Fredrickson et al., 2006). This ecological conversion from grassland- to shrubland-dominated vegetative communities has been suggested as primarily the result of the combination of regional climate change, fire suppression, and over-grazing (Grover and Musick, 1990; Johnson et al., 2000; Drewa and Havstad, 2001). Creosote (*Larrea tridentate*) bush is one such scrub-brush species that has increased in frequency as grasslands have declined (Perkins et al., 2006). Though much of the ecological research in the past three decades regarding the northern Chihuahuan Desert has been conducted in southern New Mexico (Atchley et al., 1999; Johnson et al., 2000; Drewa and Havstad, 2001; Mielnick et al., 2005; Fredrickson et al., 2006; Perkins et al., 2006; Yanoff and Muldavin, 2008; Michaud et al., 2013) and southeastern Arizona (Kurc and Benton, 2010), Campbell et al. (2013) suggested that the most characteristic representation of the Chihuahuan Desert in the United States (US) occurs within the confines of Big Bend National Park (BBNP).

In 1942, the National Park Service (NPS) purchased most of the privately held ranchland in what would become BBNP in 1944. The ranchers were then given free grazing privileges until the actual creation of the park. For those two years, livestock herds dramatically increased to take advantage of the grazing lands. By the time an estimated 50,000 head of livestock were removed in 1945, both the soil and historic vegetation cover had been severely degraded from the combination of over-grazing and untimely drought (Maxwell, 1968; Wauer, 1973; Tyler, 1975; Smithers, 1976, 1979; Wulfkuhle, 1986; Gomez, 1990; Kohout, 2001). Tornillo loam (fine-loamy, mixed, superactive, hyperthermic Ustifluventic Haplocambids; NRCS, 2014a), a weakly developed, arid-region soil, is a common soil occupying the generally flat, alluvial, valley-fill regions (NRCS, 2014b) of the northern Chihuahuan Desert within the boundaries of BBNP (Cochran and Rives, 1985; Fig. 1) upon which a historic grassland vegetation community once thrived.

The closest approximation to the historic plant community specific to Tornillo loam may be the tobosa (*Hilaria mutica*) grasslands described by Henrickson and Johnston (1986). Tobosa grasslands, or Tobosa Flats, are described as almost pure, monospecific stands of tobosa grass,

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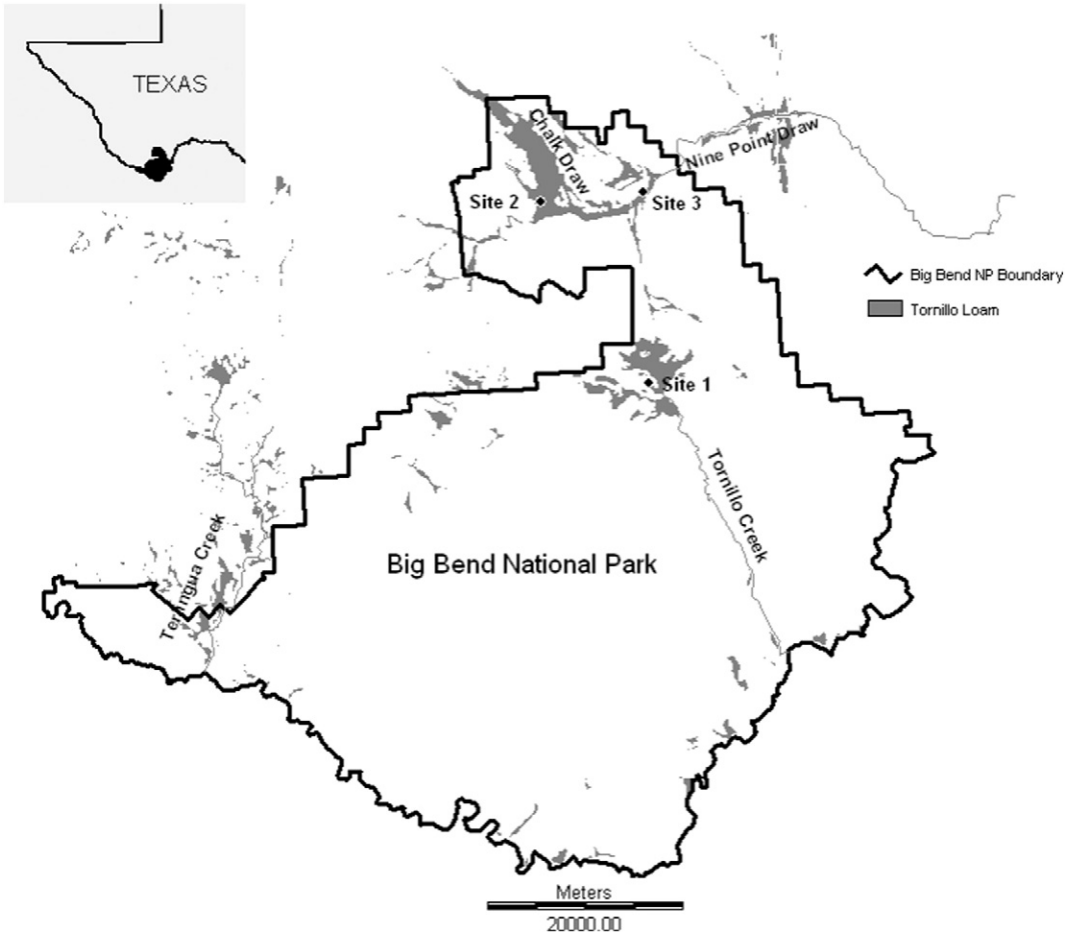

Fig. 1. Location of three sampling sites where bare soil, creosote flat, and grass patches exist on Tornillo loam in Big Bend National Park (BBNP), Brewster County, TX.

which are commonly present on fine-textured, alluvial soils without high levels of salt accumulation. Tobosa grassland differs from grama and sacaton grassland (Henrickson and Johnston, 1986). Grama grassland is dominated by species of grama grasses, such as blue grama (*Bouteloua gracilis*), black grama (*B. eriopoda*), and sideoats grama (*B. cutipendula*), which are often present on coarse-textured to sandy soils. Sacaton grassland is dominated by alkali sacaton (*Sporobolus airoides*), which grows in more saline or alkaline soils than tobosa grass.

In the 1950s, the Soil Conservation Service (SCS) focused restoration efforts on Tornillo loam in an attempt to stimulate its apparent former potential for supporting dense grass growth. During a severe drought in Texas in the 1950s, SCS made vigorous attempts to seed grasses both inside the park and on neighboring ranches. The methods used for preparing seedbeds involved using modified bulldozers to create pits or dig rows of furrows to catch and hold water and then pack down the soil to maximize seed–soil contact and to increase the length of time the seeds were exposed to water (Cox et al., 1982; Roundy and Biedenbender, 1995). Unfortunately, restoration efforts have mostly failed to promote any significant growth of native grasses, but they provided a foothold for the introduced, exotic grasses, such as Lehmann lovegrass (*Eragrostis lehmanniana*) and Johnson grass (*Sorghum halepense*). Furthermore, the area where restoration was attempted has experienced increased growth of creosote (*L. tridentate*) in the seedbed furrows giving the area an orchard appearance in aerial photographs (Fig. 2). In some places, the furrows themselves have facilitated increased erosion and gullying due to channelized water flow.

Even though Tornillo loam has been protected from grazing for over 65 years, Tornillo loam is still characterized by large areas of bare ground throughout much of its mapped extent, while infrequent, relatively small, and widely spaced grass patches remain. The grass patches, often occurring adjacent to the most severely eroded bare-soil areas, consist of nearly homogenous vegetation covering areas ranging from less than one to several hectares (Fig. 3). The grass species vary from patch to patch. In some places, the grass may be a known native species, such as tobosa grass, while other grass patches may consist primarily of introduced species (i.e., Johnson grass or Lehmann lovegrass). The remainder of the soil's vegetation cover is creosote flats, which are sparsely covered, creosote-dominated, scrub lands with little grass present and considerable exposed soil (Fig. 3).

While other soils in BBNP have shown substantial recovery from over-grazing, as measured by increased vegetation diversity and density (Wondzell, 1984), many areas of Tornillo loam appear to be still degrading through gullying and sheet erosion (Purchase, 2002b). Consequently, Science and Resource Management Department personnel at BBNP have undertaken several studies to determine what factors cause Tornillo loam to be virtually bare in some spots and densely covered with grass in other areas with the goal being to develop management practices that will mitigate erosion and encourage the recovery of grasses (Purchase, 2002a). A number of studies have shown that, once desert grasslands are protected from grazing, vegetation cover increases (Buffington and Herbel, 1965; Cottle, 1931; Wondzell, 1984). Wondzell (1984) documented increasing vegetation cover, including grasses, on several soils in BBNP. However, only one of the sampled sites was located on Tornillo loam and the results from that site were not conclusive (Wondzell, 1984).

In 1989, the NPS acquired an additional 36,400 ha of land adjoining the northwest portion of the original extent of the park. Tornillo loam