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Variation in vegetation structure and soil properties related to land use history of old-growth and secondary tropical dry forests in northwestern Mexico

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ABSTRACT

The objective of this study was to compare the vegetation structure and soil properties among old-growth tropical dry forests representing three categories of grazing intensity by cattle (light, moderate and heavy grazing) and a category of 20–30-yr-old secondary forest experiencing occasional grazing in a locality in northwestern Mexico. Within each forest type, three 0.1 ha plots located in different grazing ranges (''potreros'') were used as replicates. All woody plants (stem $\geq$ 2.0 cm diameter at 1.30 m height, DBH) were identified and measured in each plot. Mean basal area and above-ground biomass (AGB) were significantly higher in the moderately grazed old-growth forest. Species density was significantly lower in the secondary forest, where a leguminous tree species was dominant. Accumulation of AGB after 20–30 yr of secondary forest recovery accounted for 43% of the old-growth forest AGB. Soil properties varied among forest categories but did not follow a consistent pattern: mean total N and organic matter content were highest in the old-growth forest with moderate grazing; cation exchange capacity (CEC) was similar among the three old-growth forests categories, but it was significantly lower in the secondary forest compared to the old-growth forest with low grazing. Canonical Correspondence Analysis showed that CEC was highly correlated with the actual species distribution in the study area, especially with *Acacia cochliacantha* the dominant species of the secondary forest category. Resprouting capacity of the persisting species in the old-growth forests experiencing chronic disturbance could have contributed to the maintenance of some of the structural characteristics of a mature forest. Tropical secondary forests seem to accumulate AGB relatively fast, reflecting their potential for carbon storage and provision for other ecosystem services; therefore, they deserve urgent protection measures.

1. Introduction

In 1942, Howard Scott Gentry noted that only about 2% of the tropical dry forest (TDF) of the Rio Mayo region in Sonora, northwestern Mexico, was cleared for agricultural fields and annual crops (''milpas''). This condition was common throughout the range of distribution of the TDF in Mexico: small areas of crops, many abandoned fields in various stages of succession, and large areas of mature dry forest. Today, most TDFs have been seriously impacted by human activities, and presently up to 97% of the remaining 1,048,700 km^2 of TDF area worldwide are at risk (Miles et al., 2006). In Mexico, by 1990, only 27% of the TDF's original or potential cover in the whole country remained intact, while 50% had been fragmented and degraded, and 23% converted to other land uses (Trejo and Dirzo, 2000).

Transformation of the TDF in the Neotropics has been historically related to catastrophic anthropogenic disturbance, mainly slash-and-burn agriculture (Maass, 1995; Kauffman et al., 2003; Miles et al., 2006). The subsequent abandonment of agriculture and induced grasslands in these areas has led to the establishment of secondary forests usually dominated by a single leguminous tree species, such as *Acacia cochliacantha* Humb. & Bonpl. ex Willd. (Gentry, 1942; Álvarez-Yépiz, 2006), *Acacia collinsii* Saff (Ruiz et al., 2005), *Mimosa acantholoba* var. *eurycarpa* (B.L. Rob.) Barneby (Lebrija-Trejos et al., 2008), *Mimosa arenosa* (Willd.) Poir. var. *leiocarpa* (D.C.) Barneby (Ortiz, 2001; Romero-Duque et al., 2007) and *Mimosa tenuiflora* (Willd.) Poir. (Pereira et al., 2003). Although this seems to be a consistent pattern of natural TDF recovery, information regarding changes in vegetation and soil characteristics during forest succession in the dry tropics is still very limited (Mizrahi et al., 1997; Ceccon et al., 2002;

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González-Iturbide et al., 2002; Cotler and Ortega-Larrocea, 2006; Campo et al., 2007; Romero-Duque et al., 2007; Lebrija-Trejos et al., 2008; Vargas et al., 2008). In addition to the catastrophic disturbance involved in TDF transformation, these forests have also been affected worldwide by gradual long-lasting disturbance (i.e., chronic disturbance; Martorell and Peters, 2005) caused by occasional, but continuous extraction of small quantities of forest products, such as poles for fencing, fuelwood or by cattle grazing (Lindquist, 2000; Burgos and Maass, 2004; Miles et al., 2006). However, the impacts of chronic disturbance on vegetation structure and composition have not been assessed in the dry tropics in detail.

In Sonora, most ecological studies of TDFs have been conducted in the primary forest (Gentry, 1942; Krizman, 1972; Martin et al., 1998; Van Devender et al., 2000; Varela-Espinosa, 2005). In relation to the effects of human disturbance of TDF, Gentry (1942) provided a lucid description of the changes in vegetation after "milpa" abandonment in southern Sonora. However, after a long hiatus, little was added to Gentry's summary. Since the 1970s, the establishment of exotic buffel grass (*Pennisetum ciliare* L.) pastures for cattle grazing in Sonora has eradicated large areas of TDF (Búrquez et al., 2002); a much larger area than that cleared previously for slash-and-burn agriculture. Today, secondary forest succession is evident in abandoned sites (Búrquez et al., 2002), where the growth of *A. cochliacantha*, the most important successional species, reveals sites of old cultivated fields and abandoned grasslands (Martin and Yetman, 2000). Despite the widespread importance of extractive activities in TDFs, and the significant impact that livestock grazing may represent on forest composition and soil processes (Belsky and Blumenthal, 1997), no studies have addressed such impacts in this region (Lindquist, 2000).

The effects of cattle grazing on soil properties are complex; however, heavy grazing often reduces air-filled porosity and water infiltration, and increases bulk density (Greenwood and McKenzie, 2001; Sharrow, 2007). It also induces critical changes to soil chemical properties such as pH, cation exchange capacity (CEC) and organic carbon in a direction depending on several factors, being important soil mineralogy and land use history (Gebremeskel and Pieterse, 2006).

The objective of this study was to compare the floristic composition, vegetation structure, above-ground biomass (AGB) and soil properties of primary and secondary tropical dry forests sites with similar topographic and geomorphic conditions, but differing in their history of land use. Based on the premise that intensity of past disturbance is related to the current forest condition, we expected to find major differences in forests' structural characteristics and soil properties in two ways: (1) between old-growth and secondary forests (i.e., higher diversity, higher basal area and lower soil bulk density in old-growth forests) and (2) between the two extremes of grazing intensity in old-growth forests (i.e., lower cation exchange capacity and higher bulk density in the heavy grazing intensity category).

2. Materials and methods

2.1. Study area

The study was conducted in southern Sonora, northwestern Mexico, mainly within the limits of Sierra de Alamos-Río Cuchujaqui Reserve and near the city of Alamos (Fig. 1). The climate is classified as warm, semi-arid (García, 1988). Mean annual temperature is 24.3 °C and precipitation 712 mm, of which 81% fall between June and October (San Bernardo Meteorological Station, Comisión Nacional del Agua). The geology is dominated by Tertiary sedimentary rocks, especially sandstone-conglomerate units (INEGI, 1985). However, over much of the lowland area (where the study sites are located), dark, massive volcanic breccias and their regolith are evident (Gentry, 1942). The main type of vegetation is tropical dry forest, also referred to as "short tree forest" (Gentry, 1942), "selva baja caducifolia" (Miranda and Hernández-X, 1963), and "bosque tropical caducifolio" (Rzedowski, 1978). Prominent features of the Sonoran TDFs are the dominance of leguminous trees, followed in second place by Euphorbiaceae. The diversity of Cactaceae and Burseraceae, and the prominence of arborescent Fouquieriaceae and Convolvulaceae give these forests a peculiar character (Yetman et al., 1998). Total density of woody perennial plants including cacti is about 19,200 ind. ha^{-1} (Krizman, 1972). The forest canopy is highly heterogeneous, ranging from 9–15 m tall. According to Gentry (1942) it has three distinct strata, but in some areas these are difficult to distinguish. It attains its best development in the hillsides at 700–1000 m elevation and thins out at lower elevations, where it eventually transforms into a thornscrub (Búrquez and Martínez-Yrízar, in press).

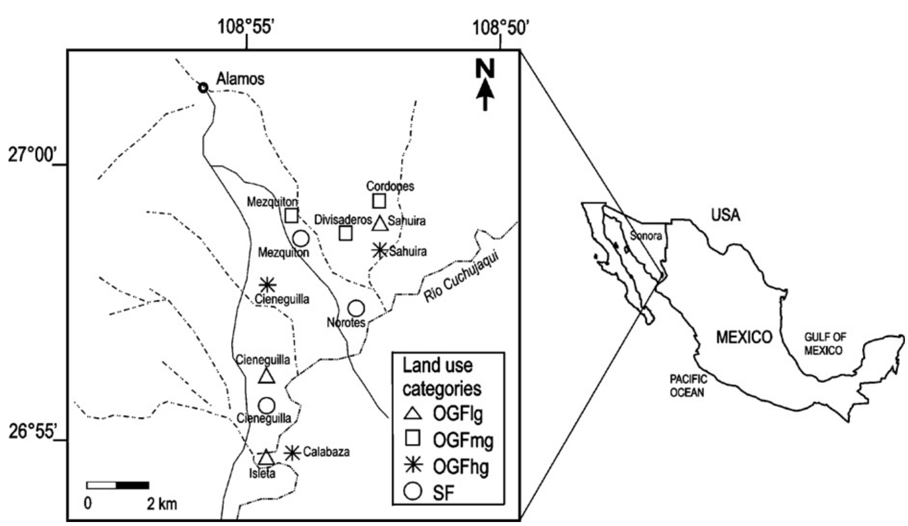

Fig. 1. Location of study sites in the Alamos region, southern Sonora, Mexico. Land use categories: OGFlg = old-growth forest with light grazing; OGFmg = old-growth forest with moderate grazing; OGFhg = old-growth forest with heavy grazing; SF = secondary forest.