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Soil carbon, nitrogen and phosphorus changes from conversion of thornscrub to buffelgrass pasture in northwestern Mexico

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ABSTRACT

In many regions of the world, land conversion of native plant communities to non-native pastures is usually associated with significant changes in soil nutrient contents. In Mexico, more than one million hectares of drylands have been converted to non-native pastures, with little knowledge on the biogeochemical consequences. We investigated the effects of non-native buffelgrass (*Pennisetum ciliare*) pasture conversion on soil carbon (C), nitrogen (N) and phosphorus (P) dynamics to understand the effects of disturbance on soil nutrient in a region of the state of Sonora. Eleven sites that formed a gradient (1–44 years) of buffelgrass establishment history where buffelgrass establishment has been practiced for at least 50 years, were studied. Soil organic C, total N and P, microbial biomass C, extractable P, and mineral N contents and basal soil respiration, were measured in samples collected during the dry and rainy seasons in buffelgrass pastures and undisturbed thornscrub. Conversion to buffelgrass pastures decreased mineral N content and basal soil respiration. Extractable P decreased in older pastures (>10 years), suggesting a potential P-limitation for the permanence of long-term buffelgrass pastures in Sonora. In contrast, we did not detect a significant reduction of soil organic C, total N and P in older pastures. This study suggests that P limitation may serve as important controls on ecosystem nutrient cycling in natural vegetation and recovery of these thornscrubs after buffelgrass pasture establishment for cattle ranching.

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1. Introduction

Drylands cover 40% of the terrestrial surface (Safriel et al., 2005). About a third of the world's population (two billion people) live in drylands, and about half of them depend on rural livehoods (Stafford-Smith et al., 2009). Thus, dryland regions have undergone intense land use change, ranging from widespread shifting cultivation agriculture to land clearing for intensive cattle ranching. These land use changes alter the structure and function of native vegetation producing a mosaic of land uses of different ages and often generate new feedbacks in terms of subsequent human use. Consequently, a major goal in assessing environmental change is to understand how biogeochemical processes respond to land use change, emphasizing the potential of a human dominated landscape to sustain continuous human use. However, successful management and dryland vegetation regeneration plans require knowledge on how the nutrient cycling, soil conditions and fertility are affected by the continuation of land use practices (Palm et al., 2007).

An extensive exploration of the effects of land cover change for grazing systems on the ecosystem biogeochemistry has been carried out with particular focus on the fertility of soils (Asner et al., 2004; Foley et al., 2005; Palm et al., 2007; Allington and Valone, 2014). These effects may be related to original fertility of soils (Post and Kwon, 2000; Conant et al., 2001). In particular, grazing areas in thornscrub and desert biomes are usually present on the less fertile soils, most of which have low organic matter and plant available nutrient contents (Geist and Lambin, 2004; D'Odorico and Porporato, 2006; Reynolds et al., 2007). This low fertility of soil in drylands probably represents a significant factor

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for long-term sustainability of managed grazing system and for the regeneration of desert and thornscrub vegetation and functioning of the ecosystem. Although dryland biomes are the regions with lowest terrestrial global productivity (Roy et al., 2001); they are frequently used for livestock management (Safriel et al., 2005).

The central issue in dry rangelands is the same as in other ecosystem: sustainable production. The human population is increasing more rapidly in drylands than in any other major biome (Safriel et al., 2005). Ecological and economic constraints on cattle ranching intensification in these regions compel the scientific community to re-examine the effects of land cover change for grass cultivation on carbon (C), nitrogen (N) and phosphorus (P) dynamics. Particularly in the drylands regions, N and P often limit production in natural ecosystems (Elser et al., 2007). Past research has focused on short-term effects of land cover change for cattle ranching on dryland soils (Asner et al., 2004). However, little is known about the medium-term effects of exotic grass establishment, including its potential to sustain rural populations.

In the desert and thornscrubs of northern Mexico, the major land use change is the conversion of natural vegetation to pastures for grass production and cattle grazing. The species introduced more frequently for this purpose has been buffelgrass (*Pennisetum ciliare* (L.) link). In the state of Sonora, it is estimated that 1.6 million hectares were cleared and planted with this alien grass (Burquez and Martinez-Yrizar, 2006). Despite the large extension, our knowledge about how drylands respond to this disturbance is poor. Buffelgrass land conversion reduces species diversity and modify the structure of the remaining vegetation (Franklin and Molina-Freaner, 2010). Previous studies that have evaluated the influence of land conversion in drylands have documented changes in water balance and alterations in soil C and N reservoirs (Castellanos-Villegas et al., 2010). However, previous studies lacked proper replication and used comparison of just one pasture and its adjacent natural habitat. Thus, our knowledge about the biogeochemical consequences of land conversion in drylands remains poor.

The present study was designed: (1) to determine the effects of land use change on the contents of organic C, total and available soil N, and total and extractable soil P, and microbial biomass content and activity and (2) to evaluate the effects of rainfall seasonality on soil and microbial C dynamics in natural thornscrub and buffelgrass pastures. We measured seasonal soil microbial biomass C (during the dry season and in the middle of the rainy season), the contents of organic soil C, as well as of total and available N and P, and basal soil respiration (BSR, an indicator of microbial activity) in sites of replicate chronosequence of buffelgrass land use in southeastern Sonora, Mexico. As in other regions, we expected soil C, N and P contents and microbial activity to be lower in buffelgrass pastures relative to thornscrub vegetation (Asner et al., 2004). Documenting the consequences of buffelgrass conversion in this region has important implications in the context of the projected biogeochemical changes expected under climate change (Delgado-Baquerizo et al., 2013). Finally, we expected a decrease of soil microbial biomass and nutrients in the rainy season in both buffelgrass pastures and natural thornscrub covers.

2. Methods

2.1. Study sites

This study was conducted around the towns of San Jose de Pimas (28° 43′N, 110° 21′W) and Tecoripa (28° 37′N, 110° 02′W), near the city of Hermosillo, Sonora (Fig. 1). The region was chosen as representative of traditional land use for cattle ranching. This production system includes long-fallow, no-input, establishment of buffelgrass pasture. The native vegetation of the region is thornscrub (Martinez-Yrizar et al., 2010). It includes a mixture of cacti (*Pachycereus pecten-aboriginum* (Engelm.) Britton & Rose, *Carnegiea gigantea* (Engelm.) Britton & Rose, *Stenocereus thurberi* (Engelm.) Buxbaum, *S. alamosensis* (Coult.) Gibson & Horak, and *Lophocereus schotti* (Engelm.) Britton & Rose, and trees (*Parkinsonia praecox* (Ruiz & Pav.) Harms, *P. microphyllum* (Torr.) Rose & Johnston, *Prosopis velutina* Wooton, *Olneya tesota* A. Gray, *Jatropha cordata* (Orteg.) Muell., *Ipomoea arborescens* (Hum. & Bonpl.) G. Don, and *Guaiacum coulteri* A. Gray (*sensu* Turner et al., 1995).

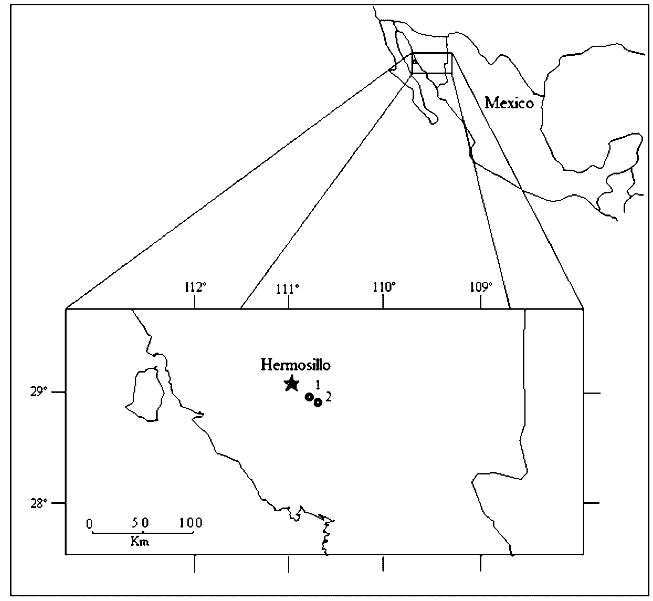

Fig. 1. Study sites were located between San Jose de Pimas (1) and Tecoripa (2), Sonora, Mexico.

The climate in the region is hot, with thermal oscillation during the year. Mean annual temperature is 22.5 °C, with 15 °C difference between the coolest and warmest months. Annual rainfall during the last 25-years period at San Jose de Pimas averaged 498 ± 48 mm (mean ± 1SE), and at Tecoripa 564 ± 31 mm, most of which falls between July and September (Fig. 2) (Comision Nacional del Agua). The soils are predominantly Aridisols, characterized by low organic matter content and low fertility, derived from sedimentary rocks (INEGI, 1988).

The introduction of buffelgrass in the region has increased the surface for cattle production (Castellanos-Villegas et al., 2010). In the last decades, 1.6×10^6 ha of the state of Sonora (approximately 10% of the State's area) was converted to buffelgrass pastures (Burquez and Martinez-Yrizar, 2006).

2.2. Approach: a gradient of buffelgrass establishment history

This study focused on patches of land that have been used exclusively for noninput and nonirrigated buffelgrass (*P. ciliare*) pastures for aproximately 50 years and that are currently under livestock grazing. A detailed description of thornscrub and buffelgrass pasture densities and cover in this region is described in Tinoco-Ojanguren et al. (2013). To determine changes in soil C, N and P dynamics, we sampled the top 20 cm of soil at 11 sites representing a gradient in establishment history from zero to 44 years (1, 3, 4, 5, 7, 12, 15, 17, 20, 30 and 44 years after buffelgrass establishment). Land conversion history was determined through interviews with landowners. Only those sites with reliable histories (as determined by corroborating information from two

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