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Conversion of thornscrub to buffelgrass pasture in northwestern Mexico: Microclimatic consequences

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ABSTRACT

Buffelgrass (*Pennisetum ciliare*) have been planted in large areas of northwestern Mexico for cattle grazing. Previous studies have documented how buffelgrass conversion affects several ecological processes; however, very few studies have documented how conversion affects local microclimate. We used data on soil temperature and moisture to document seasonal changes in microclimate as a consequence of land conversion. We describe soil and air temperature and soil moisture content in a thornscrub and an adjacent buffelgrass pasture, in open spaces and under trees, during one year. Air temperature in the pasture exceeded ~1 °C the value in the thornscrub during the colder months. Mean soil temperatures were slightly greater in the thornscrub during the dry season but during the wet season, mean temperatures were greater in the pasture reaching differences of ~2 °C. Maximum monthly soil temperatures were greater in the pasture after the wet season with values that reached 6 °C above the thornscrub. Soil moisture showed significant greater values in the thornscrub than in the pasture. Our data suggest that conversion of thornscrub to buffelgrass pasture modify the local microclimate, which in turn could influence the process of regeneration of native species persisting in pastures.

1. Introduction

Land conversion causes landscape modifications that frequently change the local climate of ecosystems (Pielke, 1998). Actually, the type of land use and land-use change are considered as one of the factors that affect local climate through modifications of energy, water and gas interchange between local vegetation and the atmosphere (Bounoua et al., 2004).

Several studies and ecosystem models recognize that an important component of ecosystem dynamics is set by the energy and water balance and by the vegetation structure of local communities (Kucharik et al., 2000; Bonan, 2002; Maass, 2003). Regarding water balance, the main input is rainfall, an important component controlling evapotranspiration rates and infiltration and runoff (Maass, 2003). Regarding energy balance, the main input comes from solar radiation which feeds the photosynthesis process, heats the environment and keeps water phases in movement (Maass, 2003). Vegetation structure (i.e. biomass, leaf area index, species composition), is considered a crucial component for maintenance and regulation of microclimate given that buffers solar radiation and intercepts rainfall (Bounoua et al., 2002, 2004). Vegetation structure exerts an important role in energy balance through sensible and latent heat, soil heat fluxes and photosynthesis (Bonan, 2002). From the net solar radiation received, a fraction is involved in photosynthesis and a great percentage (>80%) is consumed warming the air (sensible heat fluxes) and/or water evaporation (latent heat fluxes) (Maass, 2003). Soil heat fluxes warm the soil surface during the day and irradiate heat back into the atmosphere during the night (Bonan, 2002). This set of heat fluxes together with water flow is a key process in the functional dynamics of ecosystems as they control the thermal environment of soil and air (Maass, 2003). However, any modification of the vegetation structure can change this set of surface fluxes and as a consequence modify the microclimate at different scales (Bounoua et al., 2002).

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A classic example of change in vegetation structure is the conversion of natural communities to grass pastures. Around the world, large areas of forests and desertscrub have been converted to pastures for cattle grazing (Conant et al., 2001; Lambin et al., 2003). Several studies have documented how changes in plant cover modify energy and water balance, particularly evapotranspiration (ET), available soil water, infiltration and runoff (Bonan, 2002; Pielke et al., 2002; Betts, 2011; Wolf et al., 2011). It has been suggested that changes in energy and water balance are simultaneous; that is by changing moisture fluxes in converted areas, evaporation decreases and in consequence, contributes to increase surface temperature (Shukla et al., 1990; Sud et al., 1996; Costa and Foley, 2000). However, the magnitude of these processes depends on local climate conditions and seasonality. Theoretical models also predict changes in moisture fluxes and greater soil and air temperatures (Dickinson y Kennedy, 1992; Polcher, 1995; Hoffman and Jackson, 2000). The available evidence show a modification of microclimate associated with conversion in tropical and subtropical forests. However, our knowledge about the influence of pasture conversion on the microclimate in arid and semiarid regions is poor. In the arid regions of northern Mexico, deforestation is mainly associated with conversion of desertscrub and thornscrub to buffelgrass pastures (*Pennisetum ciliare* [L.] Link) for forage production and cattle grazing. This exotic grass has been successfully established in desert regions due to its drought and grazing tolerance and its ability to respond to erratic rainfall (Sanderson et al., 1999; Ramirez et al., 2001). For the state of Sonora, it has been estimated that nearly 1.6 million hectares have been converted to buffelgrass pastures (Burquez and Martinez-Yrizar, 2006). However, our knowledge on how microclimate is modified by conversion in this region is still limited. Along the Mexico–USA border, differences in grazing intensity in the Sonoran Desert has resulted in a greater proportion of bare soil and greater albedo south of the border (Balling et al., 1998). This difference in grazing is associated with greater surface temperatures and less soil moisture during the summer (Balling et al., 1998). Buffelgrass conversion is also associated with greater soil temperature and water runoff, and less evapotranspiration and water infiltration that suggest greater microclimate variation in converted areas (Castellanos et al., 2010; Celaya et al., 2015). Despite the previous results, no formal study has documented for a long period of time a continuous and detailed description of the microclimate of buffelgrass pastures, compared to adjacent natural vegetation.

In this paper, we document and compare the microclimate of a buffelgrass pasture and an adjacent thornscrub using data on soil moisture and air and soil temperature in order to evaluate how the microclimate respond to land conversion. In particular, we compare data from an entire year (03/2008–03/2009) between a natural thornscrub used as a control and an adjacent buffelgrass pasture in order to document any variation across seasons. We expect that conversion modifies seasonal microclimatic oscillations in buffelgrass pastures such as soil temperature and soil moisture content.

2. Material and methods

This study was carried out at Rancho El Diamante (28° 41′ N, 110° 15′ W), located east of Hermosillo in the state of Sonora, Mexico. In this area, mean annual temperature is 22 °C and mean annual rainfall is 450 mm (Molina-Freaner et al., 2004). Summer rains (July–September) represent 66% of the annual rainfall, with a coefficient of variation of 25%. Local vegetation is a thornscrub (Martinez-Yrizar et al., 2010), dominated by columnar cacti (i.e. *Carnegiea gigantea*, *Pachycereus pecten-aboriginum*, *Stenocereus thurberi*) and trees (i.e. *Acacia coulteri*, *A. cochliacantha*, *Parkinsonia praecox*, *P. microphyllum*, *Guaiacum coulteri*, *Ipomoea arborescens*, *Jatropha cordata*, *Prosopis glandulosa*). In this area, we selected a site with natural thornscrub vegetation and an adjacent buffelgrass pasture established in the summer of 2003. Plant cover in the thornscrub is 74.6% (Molina-Freaner et al., 2004), while in the pasture is only 8.8% (Tinoco-Ojanguren et al., 2013).

2.1. Measurements of temperature and moisture

Soil temperature sensors (HOBO U10, temperature dataloggers) and air temperature sensors (HOBO H8, Pro Series dataloggers) were installed both in the natural thornscrub and the adjacent buffelgrass pasture. All sensors were previously tested in the lab in order to corroborate that they were properly recording the same temperature under the same conditions and later installed in the field to record temperature during one year (03/2008–03/2009). In each habitat, we installed 11 sensors: ten were buried at a depth of 1 cm in order to record soil temperature, using five in open spaces between plants and five under the canopy of *P. praecox*. The remaining sensors recorded air temperature: one was installed in the thornscrub and the other one in the pasture placed at 1.5 m above the ground under the canopy of *P. praecox*. The total number of sensors in both habitats was 22.

Soil moisture was also measured in the natural thornscrub and the buffelgrass pasture. Soil volumetric water content was measured using a HH2 Delta T device equipped with a theta-probe sensor (Delta-T, Devices Ltd.). Soil moisture was measured during the entire year, starting on March 2008 and recording every two months until March 2009, except during the rainy season (July, August and September), where measurements were made every 15 days. All measurements were made in the same sites where soil temperature sensors were placed. Both in the thornscrub and the pasture, soil moisture was recorded in open spaces between plants and under the canopy of *P. praecox*, using 5 replicates. Each measurement was taken at two depths (5 and 20 cm) before sunrise in order to minimize the effect of diurnal variation during sampling across sites.

2.2. Data analysis

In order to characterize the microclimate of the thornscrub and buffelgrass pasture, monthly means and standard deviations were estimated from recorded measurements of soil and air temperature. We explored whether significant differences occur between the thornscrub and the pasture and between open spaces and under the canopy of *P. praecox*. Values of soil moisture and soil maximum and minimum temperature were analysed with repeated measures ANOVA. All statistical analysis was done using the statistical package JMP (SAS Institute, 1997).

3. Results

3.1. Mean monthly air and soil temperature

Mean monthly values of air temperature showed a similar pattern between the thornscrub and the pasture during the dry season (Fig 1). However, after the wet season, from October to March, air temperature in the pasture was ~1 °C above the thornscrub (Fig 1a). Values of mean soil temperature, both in the thornscrub and pasture, showed a similar pattern during the study period in open spaces and under the canopy; however, greater temperatures were detected in open spaces, reaching values of 40 °C (Fig. 1b and c). During summer months (June–September), open spaces in the thornscrub experienced temperatures ~1.5 °C above the values in the pasture (Fig 1b). However, this difference was reverted from October to February, where soil temperature in