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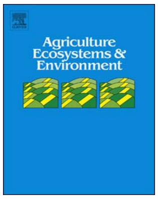

Research paper

Does precipitation affects soil respiration of tropical semiarid grasslands with different plant cover types?

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ABSTRACT

Examination of the effects of altered precipitation and atmospheric temperature patterns on ecosystem processes are an active area of research. Influences of these climate factors may change when plant cover and species composition are disturbed as a consequence of land use change altering ecosystem processes, such as soil respiration. We addressed the following question: how does experimentally manipulated reduction in the size of each precipitation event influence soil respiration fluxes (Rs) in a tropical semiarid grassland with different plant cover and species composition? Rainout shelters were installed over eight yr old planted monospecific plots (4 m^2) of *Bouteloua gracilis,* the keystone species of the grassland biome, and over mixed grassland plots in sites that recovered from abandoned agricultural land, allowing full or a 50% reduction of ambient precipitation. Soil respiration rates as well soil temperature (T_{soil}) and soil water content (SWC), as controlling factors, were monitored. Overall, SWC was the most important control for Rs explaining ~70% of its variability, followed by T_{soil} which explained ~25% and plant cover type having a minor effect (3%) explaining Rs variability. Still, Rs exhibited differential responses when comparing plant cover types; SWC in the mixed grassland had up to 90% relative influence on Rs as compared to 10% by Tsoil. In contrast, Rs rates in monospecific *B. gracilis* plots exhibited less overall variability considering SWC (55–60%) and T_{soil} (40–45%), suggesting that grasslands dominated by the keystone species are more resilient and better buffer the effects of extreme climatic drought conditions on ecosystem processes.

1. Introduction

Drylands comprise a wide diversity of ecosystems that cover ca. 40% of the terrestrial surface (Lal, 2004). Generally, precipitation (PPT) patterns in drylands are characterized by their scarcity and the high intra and inter-annual variability, in which small rainfall events in form of “pulses” account for a large proportion of annual water inputs (Sala and Lauenroth, 1982). Interannual variability in PPT across drylands spans such a large range that rainfall events are considered hot spots, as they control the variability in regional carbon fluxes (Jung et al., 2011; Blazewicz et al., 2014). Ahlström et al. (2015) have reported that it is this high variability in PPT that controls the interannual variability of the global C sink. Global circulation models forecast that the arid and semiarid regions will have a 10 and a 20% reduction of summer and winter PPT, respectively, by the end of the 21st Century (Christensen et al., 2007) *i.e.,* under current CO_2 emission scenarios. Scenarios also project larger PPT events with longer periodicity (occur less frequently) (Easterling et al., 2000; Houghton, 2001). These expected changes in climate change drivers (i.e. air temperature and precipitation regimes) are projected to increase soil respiration rates globally, *i.e.*, it will increase C losses from the ecosystem (Schlesinger and Andrews, 2000).

Land use change is attributed to the 12.5% of total CO_2 emissions to the atmosphere at the global scale (Houghton et al., 2012; IPCC, 2013). While land use change is usually described as conversion or modification of land cover (Chapin et al., 2011) to increase the production of a certain commodity, with clear impacts on ecosystem structure and function, relatively little is know about land abandonment and its legacy effects on fundamental ecosystem processes (Foley et al., 2005), as those on the biogeochemical and biophysical fluxes, including, the cycling of carbon, water, energy. Previous studies have demonstrated that

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shifts in plant cover or dominant species may alter the net radiation budget and ecosystem energy balance (Chapin et al., 2008; He et al., 2015). Similarly, changes in species composition has been associated with changes in soil mineralization processes (Steltzer and Bowman, 1998), hydrological fluxes (Pérez-Suárez et al., 2014), and photosynthesis and respiration rates (Delgado-Balbuena et al., 2013).

In this context, a change in plant cover that induces variations in the energy balance, the hydrological cycle and in the amount and quality of organic matter, suggests that factors such as soil temperature and soil moisture that control soil respiration rates may also concurrently change (Raich et al., 2002; Raich and Schlesinger, 1992). Other factors that control soil respiration rates include; soil organic matter quality and quantity (Taylor et al., 1989), root and microbial biomass, root nitrogen content (Ryan et al., 1996), soil acidity, soil texture, and site productivity (Raich and Potter, 1995; Raich and Schlesinger, 1992). For interacting controlling factors, drought has been shown to decrease the degree of control by soil temperature, and re-enforcing the degree of control of soil water content (SWC) on Rs (Law et al., 1999; Reichstein et al., 2002), which depends principally on the magnitude and periodicity of individual rain events (Lee et al., 2002). Precipitation in the semiarid grassland biome of Mexico is characterized by predominantly small events, where ~60% of the annual PPT fall as events < 5 mm d^{-1} (Delgado-Balbuena, 2016). In addition, during the rainy season there is a predominance of short inter-event dry periods (inter-event periods < 10 days), whereas long dry periods may last up to six to nine months (Easterling et al., 2000). PPT events that follow after a medium to long dry period coincide with pulsed losses of CO_2 from the ecosystem to the atmosphere, that are likely the result of SWC-induced activation of soil microorganisms *i.e.*, Birch effect (Birch, 1958, 1964; Rey et al., 2002), and/or physical gas displacement of CO_2 by water in soil pore spaces (Huxman et al., 2004). Predicted changes in the PPT regime over the drylands of Mexico (Christensen et al., 2007) suggest marked alterations in ecosystem process rates controlling the cycling of CO_2, and the overall carbon balance in these semiarid regions (Delgado-Balbuena, 2016).

The tropical semiarid grassland biome in central Mexico is currently undergoing unprecedented directional changes in the abundance of its keystone grass species. *Bouteloua gracilis* populations have declined due to massive conversion of grasslands to agricultural land, urbanization, road infrastructure and overexplotation as a livestock production system. For instance, vast extensions of grassland that had been converted to rainfed agriculture about 50 to 80 years ago, have been abandoned due to harsh climatic conditions with decadal periods of drought (Arredondo et al., 2005). Several decades of vegetation recovery have led to the establishment of less grazing-palatable subordinate C_4 grass species and several C_3 annual herbs (e.g. *Muhlenbergia rigida, Aristida divaricata, B. hirsuta, B. scorpioides;* Arredondo et al., 2005; Medina-Roldan et al., 2007). Previous comparative studies with these transformed secondary grasslands have shown that these modified plant communities alter the fraction of total intercepted net radiation by the canopy, air temperature, and SWC (Delgado-Balbuena et al., 2013; Medina-Roldan et al., 2007). These altered grassland communities also differ in their inherent traits (Eviner and Chapin, 2003) such as specific leaf area (Delgado-Balbuena et al., 2013) and shoot and root biomass (Medina-Roldan et al., 2007), which in turn, feed back on ecosystem functions. Keystone species functional traits of *B. gracilis* reduce the incidence of solar radiation reaching the soil surface, lower near-soil air temperatures (Delgado-Balbuena et al., 2013), enhance infiltration rates of PPT, soil water retention, the efficiency in extracting soil water (Medina-Roldan et al., 2007) and exhibit higher water use efficiency (Arredondo et al., 2016) than those of altered mixed-species grasslands establishing after land abandonment.

We addressed the question on how does experimental manipulation of PPT (i.e. 50% reduction of each event) influence soil respiration rates (Rs) in mixed species grasslands on former agricultural land compared to 10 year old *Bouteloua gracilis* plots. We expected reduced PPT would mimic natural drought and thus result in a decline in soil CO_2 emissions to the atmosphere compared to natural PPT (H1). Further, we expected reduced PPT would reduce Rs to a greater extent in altered, mixed grasslands compared to monospecific *B. gracilis* grasslands, due to warmer and drier micrometeorological conditions in the former setting (H2). Lastly, we expected experimentally reduced PPT would lessen the degree of control of soil temperature on Rs, and this effect would be greater in mixed grassland conditions with potentially higher evaporation rates compared to the *B. gracilis* grasslands (H3).

2. Materials and methods

The study was carried out at the *Vaquerias* grassland research station of the National Institute for Agriculture, Animal Production and Forestry Research (INIFAP) located in the geographic subprovince Llanos de Ojuelos, Jalisco, México (21°46′52.25″N, 101°36′29.56″W, 2240 m.a.s.l.). The study area is situated in the southernmost extension of the shortgrass steppe biome in North America (Aguado-Santacruz and Garcia-Moya, 1998), with a topography characterized by plain terrains with gentle rolling hills (COTECOCA, 1979). Soils are Xerosols with pH values ranging between 5.5 and 6.5, and with a low content of organic matter and cation exchange capacity (Aguado-Santacruz and Garcia-Moya, 1998). The climate is semiarid with an average of 424 mm annual rainfall over the last 30-y, with most of the PPT occurring in the summer months (July–September) and with an average annual temperature of 18 °C (COTECOCA, 1979).

2.1. Rainout shelters and plot structure

In 2011, we installed a rain manipulation experiment with rainout shelters to reduce the amount of natural annual PPT (Yahdjian and Sala, 2002) on plots (2.0 × 2.0 m) with two plant cover types: 1) 10-y old transplants of adult *B. gracilis* tussocks and 2) 70-y old mixed grassland recovered from abandoned agriculture. For each plot, V-shaped acrylic strips (0.11 × 2.2 m) without UV-filters (ACRYLITE® GP-OP4, Evonik Cyro LLC, Parsippany, NJ) were installed atop of two parallel pairs of metallic supports (2.00 m apart) at different heights (1.10 m in the back and 0.90 m in the front of plots) to obtain a slope to drain the rain (Fig. 1a). We installed nine acrylic strips per plot (1.98 m^2 plot cover = 49.5%) attempting to remove ~50% of each PPT event. Around each plot, a 25 cm wide aluminum sheet was inserted 15 cm into the ground to protect plots from both surface runoff and horizontal subsurface water flows from neighboring areas, i.e., other water inputs. The inclined V shaped strips drained the intercepted rain into a covered aluminum gutter that was connected by a hose to a 40 l container (Fig. 1a). The actual PPT removed on each plot was estimated as the difference between the total PPT recorded at each event with two rain gauges (mm) (All-weather rain gauge, Forestry Suppliers Inc., Jackson, MS) installed at the opposite ends of the research area, and the volume of water collected in the containers. This allowed us to account for the effects of occasional lateral storms and unintended breakage of acrylic strips.

The monospecific grassland plots included only the dominant species *B. gracilis,* whereas the mixed grassland consisted of a community of the most common species: *B. gracilis*, *B. hirsuta*, *B. scorpioides*, *Microchloa kunthii*, *Muhlenbergia rigida*, *Paspalum* sp., *Panicum obtusum*, several annual herbs and the subshrub *Isocoma veneta* (Aguado-Santacruz et al., 2002). Seven replicates were installed for each treatment combination. To account for potential artifact effects of rainout structures on local radiation and wind conditions, rainout shelters were installed on both control and treatment plots. However, in case of the control plots, the collected PPT was homogenously applied on the control plots with a watering can the day after the PPT event.