Soil Biology & Biochemistry xxx (2014) 1–10

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Hot spots, hot moments, and spatio-temporal controls on soil CO_2 efflux in a water-limited ecosystem

Elievf Leon [a], Rodrigo Vargas [b,*], Stephen Bullock [a], Eulogio Lopez [a], Alan Rodrigo Panosso [c], Newton La Scala Jr. [d]

[a] Departamento de Biología de la Conservación, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Ensenada, BC, Mexico
[b] Department of Plant and Soil Sciences, Delaware Environmental Institute, University of Delaware, Newark, DE 19717, USA
[c] Universidade Estadual Paulista, Departamento de Matemática – FEIS/UNESP, Ilha Solteira, SP, Brazil
[d] Universidade Estadual Paulista, Departamento de Ciências Exatas – FCAV/UNESP, Jaboticabal, SP, Brazil

A R T I C L E I N F O

Article history:
Received 10 December 2013
Received in revised form
5 May 2014
Accepted 11 May 2014
Available online xxx

Keywords:
Drought
Heterogeneity
Kriging
Semivariogram
Soil respiration
Temperature sensitivity

A B S T R A C T

Soil CO_2 efflux is the primary source of CO_2 emissions from terrestrial ecosystems to the atmosphere. The rates of this flux vary in time and space producing hot moments (sudden temporal high fluxes) and hot spots (spatially defined high fluxes), but these high reaction rates are rarely studied in conjunction with each other. We studied temporal and spatial variation of soil CO_2 efflux in a water-limited Mediterranean ecosystem in Baja California, Mexico. Soil CO_2 efflux increased 522% during a hot moment after rewetting of soils following dry summer months. Monthly precipitation was the primary driver of the seasonal trend of soil CO_2 efflux (including the hot moment) and through changes in soil volumetric water content (VWC) it influenced the relationship between CO_2 efflux and soil temperature. Geostatistical analyses showed that the spatial dependence of soil CO_2 efflux changed between two contrasting seasons (dry and wet). During the dry season high soil VWC was associated with high soil CO_2 efflux, and during the wet season the emergence of a hot spot of soil CO_2 efflux was associated with higher root biomass and leaf area index. These results suggest that sampling designs should accommodate for changes in spatial dependence of measured variables. The spatio-temporal relationships identified in this study are arguably different from temperate ecosystems where the majority of soil CO_2 efflux research has been done. This study provides evidence of the complexity of the mechanisms controlling the spatio-temporal variability of soil CO_2 efflux in water-limited ecosystems.

© 2014 Published by Elsevier Ltd.

UNCORRECTED PROOF

1. Introduction

Water-limited environments occupy nearly 40% of terrestrial habitats (Loveland et al., 2000), and changes in timing and magnitude of precipitation pulses will influence the biophysical mechanisms that regulate the carbon cycle in these globally distributed ecosystems (Schimel, 2010). These ecosystems are defined by high variability in seasonal and inter-annual precipitation, high rates of potential evapotranspiration, and precipitation pulses that drive biotic activity until available water is depleted (Noy-Meir, 1973; Reynolds et al., 2004; Collins et al., 2008). It is estimated that 241 Pg C is stored in these ecosystems (Lal, 2005), which represent nearly 16% of total terrestrial organic carbon in the first meter of soil (Post et al., 1982; Jobbagy and Jackson, 2000).

A high-priority objective in carbon cycle science is to understand the spatial and temporal controls of CO_2 dynamics in terrestrial ecosystems. Identifying these controls is important for improving model architecture (i.e., mathematical equations that represent biophysical processes) and parameterization (Luo et al., 2008; Carvalhais et al., 2010). Failing to properly represent these controls could over- or under-estimate CO_2 fluxes in terrestrial ecosystems. For example, a recent meta-analysis has shown that process-based ecosystem models tend to misrepresent ecosystem respiration in water-limited ecosystems (Vargas et al., 2013a). Therefore, more information about the temporal and spatial controls of different components of ecosystem respiration is needed to better represent ecosystem CO_2 dynamics.

The largest component of ecosystem respiration is soil CO_2 efflux (i.e., soil respiration). This flux is the main source of CO_2 emissions from terrestrial ecosystems to the atmosphere with a

* Corresponding author. Department of Plant and Soil Sciences, University of Delaware, Newark, DE 19716, USA. Tel.: +1 302 831 1386.
E-mail address: rvargas@udel.edu (R. Vargas).

http://dx.doi.org/10.1016/j.soilbio.2014.05.029
0038-0717/© 2014 Published by Elsevier Ltd.

potential flux of 98 Pg C yr^{-1} (Bond-Lamberty and Thomson, 2010). Soil CO_2 efflux varies temporally in water-limited ecosystems and these variations have been linked to changes in timing and intensity of precipitation (Thomey et al., 2011; Vargas et al., 2012), soil temperature (Cable et al., 2010), and plant phenology (Barron-Gafford et al., 2011). Furthermore, precipitation pulses create "hot moments" in these ecosystems when metabolic activity is increased (Jenerette et al., 2008) and higher soil CO_2 efflux rates are observed (Kim et al., 2012). Hot moments are defined as short periods of time that show disproportionately high soil CO_2 efflux relative to longer intervening time periods, and could be important for the annual carbon balance in water-limited ecosystems. The concept of hot moments is important in water-limited ecosystems because they are considered to be areas with low metabolic activity. Nonetheless, the rate of change from baseline soil CO_2 efflux could be >9000% during a hot moment; typically associated with a precipitation pulse following a dry period in water-limited ecosystems (Kim et al., 2012).

Hot spots are spatially defined areas that show disproportionately high soil CO_2 efflux relative to the surrounding area. Several studies have linked spatial variability of soil CO_2 efflux in water-limited ecosystems to changes in soil texture (Cable et al., 2008), soil organic matter fractions (Almagro et al., 2013), vegetation types (Maestre and Cortina, 2003; Vargas et al., 2010), and inter-canopy spaces (Barron-Gafford et al., 2011). To quantify and predict the spatial variability of soil CO_2 efflux many studies have applied geostatistical approaches (e.g., semivariograms, kriging); however, few studies have been conducted in water-limited ecosystems (La Scala et al., 2000; Stoyan et al., 2000; Panosso et al., 2009; Herbst et al., 2011).

The primary objective of this study was to determine the temporal and spatial variation of soil CO_2 efflux in a Mediterranean water-limited ecosystem. Specifically, we explored hot moments (i.e., sudden temporal high fluxes) and hot spots (i.e., spatially defined high fluxes) of soil CO_2 efflux within this ecosystem. We used an array of simple empirical models to represent the temporal variability of soil CO_2 efflux, as well as principal component analysis and geostatistical techniques to identify spatial relationships among variables and to quantify the degree of spatial dependence. Based on previous knowledge of water-limited ecosystem we postulate three hypotheses. First, soil CO_2 efflux will follow a temporal pattern driven primarily by soil water content and secondarily by soil temperature. This statement is based upon the understanding that soil water content modulates the plant and microbial contribution to soil CO_2 efflux and the temperature dependence of this flux in water-limited ecosystems (Almagro et al., 2009; Cable et al., 2010; Carbone et al., 2011; Vargas et al., 2012). Second, the beginning of the rainy season will trigger a hot moment of high soil CO_2 efflux, potentially driven by a priming effect after the dry-hot summer months (Kuzyakov, 2010). Third, soil CO_2 efflux spatial dependence will change between dry and wet seasons as a result in changes in soil moisture, plant activity (associated with root biomass and leaf area index), or soil temperature. Therefore, it is likely that soil CO_2 efflux spatial dependence would be higher during the wet season as a result of higher ecosystem metabolic activity when water is not a limiting factor.

2. Materials and methods

2.1. Study site

The study site, El Mogor, is located at 406 m.a.s.l. in the Valle de Guadalupe, Baja California (32.03017N and 116.604219W), Mexico. The climate at El Mogor is semiarid Mediterranean, with warm-dry summers and cool-wet winters. Chaparral vegetation is characteristic of Mediterranean shrublands and these ecosystems are common across California and Baja California in North America (Hellmers et al., 1955; Minnich and Chou, 1997). The mean annual temperature is 17 °C and mean annual precipitation is 309 mm (average of years 1980–2009, Fig. 1). Rainfall typically occurs during the cool-wet winters (November–April) with mean monthly temperatures of 11–14 °C and monthly precipitation of 18–63 mm. Meanwhile, the warm-dry months (May–October) have mean monthly temperatures of 16–21 °C and monthly precipitation of 1–6 mm (Fig. 1a). Soils at the study site are shallow (approximately 30 cm of depth) and developed from granitic parent material. Soil texture is sandy loam (75% sand, 14% silt, and 11% clay). For a detailed description of soils at the study site see Franco-Vizcaino and Sosa-Ramírez (1997). The study site El Mogor is part of the Mexican eddy covariance network (MexFlux; Vargas et al., 2013b).

Vegetation at El Morog is characterized by a mixture of chaparral and less-sclerophyllous species with a mean height of 1 m. The species with the greatest ground cover at the study site are: *Adenostoma fasiculatum*, *Ornithostaphylos oppositifolia*, *Cneoridium dumosum*, *Salvia apiana*, and *Lotus scoparius*. The site was severely burned in 1988 and has recovered rapidly over the last 24 years; however, wildfires are an expected feature of the natural cycle of chaparral (Franco-Vizcaino and Sosa-Ramirez, 1997; Keeley and Fotheringham, 2001).

We established a 100 × 50 m sampling area within a representative location of the ecosystem in September 2011. Within this

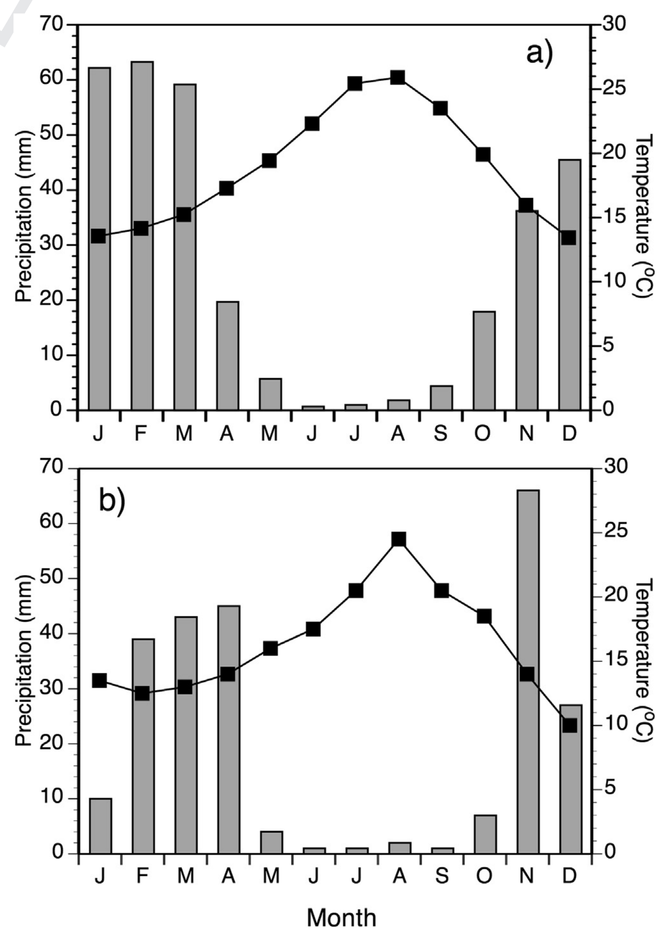

Fig. 1. Mean monthly precipitation (mm) and mean monthly temperature (°C) during the period 1980–2009 (a) and during the study period (September 2011–August 2012; b) at El Mogor, Baja California, Mexico. The *x*-axis label is the first letter of each month.

UNCORRECTED PROOF

Please cite this article in press as: Leon, E., et al., Hot spots, hot moments, and spatio-temporal controls on soil CO_2 efflux in a water-limited ecosystem, Soil Biology & Biochemistry (2014), http://dx.doi.org/10.1016/j.soilbio.2014.05.029

Download English Version:

https://daneshyari.com/en/article/8364456

Download Persian Version:

https://daneshyari.com/article/8364456

Daneshyari.com