European Journal of Soil Biology 82 (2017) 10–16

Contents lists available at ScienceDirect

European Journal of Soil Biology

journal homepage: http://www.elsevier.com/locate/ejsobi

Wetting-drying cycles influence on soil respiration in two Mediterranean ecosystems

Lourdes Morillas [a, b, *], Javier Roales [a], Miguel Portillo-Estrada [c], Antonio Gallardo [a]

[a] Departamento de Sistemas Físicos, Químicos y Naturales, Universidad Pablo de Olavide, Ctra. Utrera Km1, Seville, Spain
[b] Department of Sciences for Nature and Environmental Resources, University of Sassari, Via Enrico de Nicola, n 9, 07100 Sassari, Italy
[c] Centre of Excellence PLECO (Plant and Ecosystems), Department of Biology, University of Antwerp, Universiteitsplein 1, B-2610 Wilrijk, Belgium

ARTICLE INFO

Article history:
Received 22 February 2017
Received in revised form
26 July 2017
Accepted 31 July 2017
Available online 8 August 2017

Handling editor: Y. Kuzyakov

Keywords:
Soil moisture
CO_2 efflux
Mineral nitrogen
Phosphate
Resin mineral N
Carbon mineralization

ABSTRACT

This study assesses which factors are involved in the soil respiration (Sr) response to wetting-drying cycles in two Mediterranean ecosystems. We analysed Sr, mineral nitrogen, ion-exchange resin mineral nitrogen, and phosphate levels at weekly intervals over one year in two Mediterranean ecosystems with contrasting characteristics: a pine forest with high levels of organic matter and nutrients and a shrubland with low carbon and nutrients availability. Higher Sr was detected in the pine forest (0.12 −0.76 g CO_2 m^{-2} $hour^{-1}$) than in the shrubland (0.04–0.67 g CO_2 m^{-2} $hour^{-1}$). For both sites, Sr increased during wet periods and decreased during dry periods. Compared with Sr in the pine forest, the trend observed for resin mineral nitrogen was the opposite. No pattern was observed for resin mineral nitrogen at the shrubland site, or for mineral nitrogen or phosphate at either site. The initial water status of the wetting-drying cycles determined the Sr response, whereas the length of the drought period before the rewetting event had no effect. The impact of the initial soil water content on Sr played a crucial role when the wetting-drying events occur in a dry soil, having a secondary role in wet soils. Finally, soil water status drove Sr during the growing season in both ecosystems; however, soil temperature had no effect on CO_2 efflux. In a changing world with projections of intensifying wetting-drying events, our results highlight the influence of soil water status on respiration rates, especially when these events occur in a dry soil.

1. Introduction

Soil respiration involves the emission of CO_2 due to organic matter decomposition resulting from the metabolic processes of soil microbes and plant roots. Although the contribution of soil respiration is up to three-quarters of total ecosystem CO_2 effluxes into the atmosphere [1], we have only a limited understanding of the variability across ecosystems and the controlling factors [2]. In Mediterranean ecosystems, low soil moisture limits the response of soil carbon (C) and nitrogen (N) mineralization to increases in temperature [2,3]. Climate models project longer dry periods and more intense rainfall events expected in these areas [4]. Given the key role of soil moisture in soil biogeochemical processes in these ecosystems, these projected climatic changes might cause long-term changes in soil C and N pools [5]. With the relatively limited stock of organic C in Mediterranean soils these ecosystems are particularly sensitive to climate change because any change in the precipitation pattern could alter soil respiration and potentially deplete stores of soil C.

Although Mediterranean ecosystems have been classically underestimated, the effects of soil temperature and moisture on both respiration rates [6] and N cycling [7] have been the focus of much research in the last decade in this area. These studies have provided valuable insights into the effects of wetting-drying cycles on soil processes, but many of them have produced in inconsistent findings (for a review, see Borken and Matzner [8]). Hence, more information is required to achieve a deeper understanding of the functioning of these ecosystems.

Studying the mineralization rates of soil C and N in Mediterranean ecosystems is particularly challenging because of the difficulties entailed by the marked seasonality of precipitation and the high spatial heterogeneity of soil properties and vegetation. This heterogeneity is particularly acute in shrublands, in which the

* Corresponding author. Department of Sciences for Nature and Environmental Resources, University of Sassari, Via Enrico de Nicola, n 9, 07100 Sassari, Italy.
E-mail address: lourdesmorillas@msn.com (L. Morillas).

http://dx.doi.org/10.1016/j.ejsobi.2017.07.002
1164-5563/

patchy distribution of vegetation leads to increased localization of soil resources under shrub canopies [9]. Additionally, few studies have considered the effect of wetting-drying cycles on phosphorous (P) cycling [10], although soil P might be highly limiting in terrestrial ecosystems as a consequence of increased atmospheric N deposition [11]. Jenerette and Chatterjee [12] reported that the microbial response to a wetting-drying event is triggered by soil wetting but is regulated by resource limitation, demonstrating the relevance of the soil nutritional status in these types of studies. We evaluated the changes in soil respiration rates, mineral N (defined as the sum of ammonium and nitrate), resin-mineral N, and PO_4^{3-} during natural wetting-drying cycles in two Mediterranean ecosystems distant few km between each other. The two study sites have contrasting levels of soil organic matter and nutrients: a pine forest with high levels of organic matter and soil nutrients, most likely the result of the dense plant-canopy environment, and a less dense shrubland with low C and nutrient availability. A comparison of these two spatially close but largely different ecosystems can provide valuable information on how soil respiration is modulated by the local soil conditions.

Our goal was to assess which factors are involved in the soil respiration response to wetting-drying cycles. We conducted an intensive weekly sampling for one year to capture the entire intra-seasonal variability of the studied variables and to identify different wetting-drying cycles within each season. This survey explored any emergent and common patterns in soil respiration, N mineralization and mineral P responses to these wetting-drying cycles. By considering whether the wetting events occurred in a previously dry or wet soil, we attempted to assess the effect of additional rewetting on the dynamics of the variables as a function of prior soil moisture. We also assessed the effect of the length of the drying events before rewetting because it may play a key role in the response of soil respiration to sudden changes in soil moisture, which may be further modulated by both soil organic matter and soil texture [6,13]. Experimental set-up of this type gains importance in ecosystems with such features as high spatial heterogeneity of soil properties and vegetation similar to that observed in semiarid areas.

We hypothesized that (i) given the major differences between the two study sites, the responses of soil respiration rate and mineral N and P to the wetting-induced pulses would produce distinct patterns in the two Mediterranean ecosystems; (ii) soil respiration would be driven by soil water content and temperature at the two study sites, and (iii) both the length and severity of a drought period before rewetting would determine the response of soil respiration to rapid changes in the soil water status.

2. Materials and methods

2.1. Study area

This study was conducted in two ecosystems, pine forest and shrubland, in southwestern Spain (37° 21′N; 5° 56′ W), both with a typical Mediterranean climate. The distance between the study sites is 14.5 km. The 30-year average rainfall and temperature at the experimental sites were 565.7 mm and 19.0 °C, respectively. The study year (October 2009–October 2010) was wetter than normal, with rainfalls of 852.6 mm in the pine forest and 845.7 mm in the shrubland. The soils in these areas have a typical A(B)C profile with a sandy clay loam and loamy sand texture in the pine forest and the shrubland respectively, as defined by the United States Department of Agriculture [14]. Table 1 presents the primary properties of these soils. The pine forest is composed primarily of *Pinus pinea* L. with scarce annual herbs and forbs in the understory. The shrubland is dominated by *Quercus coccifera* L., *Cistus albidus* L., *Genista hirsuta* Vahl., and *Arbutus unedo* L.

Table 1
Soil physical and chemical properties of the top 10 cm for the pine forest and shrubland sites. Asterisks indicates significant differences between the two study sites ($p < 0.05$). Variables analyzed for monitoring purpose were calculated averaging all obtained data during the whole year.

Analyses for general soils description (n = 24)	Pine Forest		Shrubland	
	Mean	SE	Mean	SE
Clay (%)*	23.6	1.71	6.63	0.80
Silt (%)	12.8	3.64	12.5	0.69
Sand (%)*	63.6	5.26	81.0	0.36
Bulk density (g cm^{-3})*	1.16	0.07	1.41	0.09
pH*	7.2	0.03	5.49	0.06
Organic matter (%)*	2.84	0.21	1.91	0.17
Phenols (mg kg^{-1} soil)*	10.42	1.56	6.61	0.43
Hexoses (mg kg^{-1} soil)*	39.33	0.2.35	12.03	0.34
Aromatic compounds (mg kg^{-1} soil)*	127.74	9.29	32.8	3.06
Total N (%)*	0.15	0.02	0.10	0.01
MB-N (mg kg^{-1} soil)*	62.7	1.88	35.6	1.46
DON (mg kg^{-1} soil)*	12.0	0.39	8.82	0.48
Ca (meq $100g^{-1}$)*	12.2	0.82	8.08	0.52
Mg (meq $100g^{-1}$)*	1.16	0.08	0.51	0.03
K (meq $100g^{-1}$)*	0.62	0.03	0.16	0.01
Na (meq $100g^{-1}$)*	0.31	0.01	0.18	0.02
Analyses for monitoring purposes (n = 312)				
Water content (%)*	12.4	0.53	7.98	0.33
Water holding capacity (g H_2O 100 g^{-1} soil)*	45.87	0.58	27.73	0.76
Respiration (gr CO_2(m^2 h)$^{-1}$)*	0.33	0.01	0.26	0.01
Mineral N (mg kg^{-1} soil)*	3.54	0.22	1.73	0.16
NH_4^+-N (mg kg^{-1} soil)*	0.32	0.04	0.35	0.08
NO_3^--N (mg kg^{-1} soil)*	3.22	0.23	1.38	0.16
Mineral N Resins (μg cm^{-2} day^{-1})	0.72	0.03	0.83	0.04
Sodium bicarbonate PO_4^{3-}-P (mg kg^{-1} soil)*	2.37	0.10	0.53	0.03
Mineral N/PO_4^{3-}-P*	1.49	0.14	3.26	1.16

2.2. Soil sampling

To explore the temporal dynamics of soil respiration and nutrient availability, we conducted soil sampling at weekly intervals over the course of one year (October 2009 to October 2010). Soil sampling was performed each Friday for the pine forest and each Saturday for the shrubland. The sampling areas were approximately 4000 and 3000 m^2 for the pine forest and shrubland, respectively. Each site was considered a single plot, and a minimum distance of 3 m between both soil samples and respiration measurements and between measurements performed in different days was used to ensure that pseudoreplication was avoided. Six soil samples from each study site were randomly collected to a depth of 10 cm of the soil profile on each sampling date with a circular soil corer (5 cm diameter × 10 cm height). We removed the litter layer from the topsoil before sampling and then transported the samples in refrigerated plastic bags to the laboratory for storage at 3 °C. The soil samples were sieved to remove roots and rocks, processed within three days of collection, and subsequently analysed separately. On each sampling date at six randomly chosen spots located on the bare soil, soil respiration rates were measured as the surface CO_2 efflux using a portable soil respiration system (EGM-4, PP SYSTEMS) with a chamber 10 cm in diameter and 15.5 cm in height. According to the manufacturer's protocol, the chamber was held in the air to flush it out before each measurement and then placed on the soil for determination of soil respiration rates. Soil temperature was monitored via a digital soil thermometer at six randomly chosen spots different from those at which the soil samples were collected. Both the soil respiration and temperature were systematically measured from