Geoderma 237–238 (2015) 1–8

Contents lists available at ScienceDirect

Geoderma

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

Both altitude and vegetation affect temperature sensitivity of soil organic matter decomposition in Mediterranean high mountain soils

Alba Gutiérrez-Girón [a,*], Eugenio Díaz-Pinés [b], Agustín Rubio [c], Rosario G. Gavilán [a]

[a] Departamento de Biología Vegetal, Facultad de Farmacia, Universidad Complutense de Madrid, Madrid, Spain
[b] Institute of Meteorology and Climate Research, Atmospheric Environmental Research (IMK-IFU), Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany
[c] Departamento de Silvopascicultura, Escuela Técnica Superior de Ingenieros de Montes, Universidad Politécnica de Madrid, Madrid E-28040, Spain

ARTICLE INFO

Article history:
Received 25 April 2014
Received in revised form 6 August 2014
Accepted 9 August 2014
Available online 23 August 2014

Keywords:
Respiration sensitivity to temperature
Microbial respiration
Shrub encroachment

ABSTRACT

The aim of this work was to study the sensibility to warming of soil organic matter (SOM) decomposition in Mediterranean high mountain areas. Thus, we investigated the effects of temperature, C availability and vegetation in a Mediterranean high-mountain area in relation to SOM decomposition patterns. Along an altitudinal gradient (from 2100 to 2380 m a.s.l.) in Central Spain mountains, we assessed the altitudinal shifts in soil organic C (SOC), soil nitrogen (N), dissolved organic carbon (DOC), microbial biomass C (MBC), microbial respiration, microbial respiration sensitivity to temperature (Q_{10}) and C availability index (CAI). Furthermore, we tested the differences in SOM decomposition rates between grasslands and shrub vegetation. SOC, DOC, N content, MBC, microbial respiration and CAI decreased, while Q_{10} increased with increasing altitude. In the grassland, MBC and microbial respiration were positively correlated to SOM. Q_{10} was positively correlated to pH and negatively correlated to substrate-induced microbial respiration. Soils below shrubs showed lower microbial respiration rates, lower CAI, and higher Q_{10} than soils below grassland. However MBC, DOC and soil N content were higher below shrubs. The results suggest that a rise in temperature would enhance SOM decomposition rates in grasslands more dramatically at higher altitudes, since they are more sensitive to temperature increases. The SOC accretion observed below shrubs may be due to the lower respiration rate of soil microorganisms, possibly determined by lower C substrate availability below shrubs. This result suggests a higher recalcitrance of shrub litter compared to grassland litter. Nevertheless, SOC in shrubland may be released at a higher rate due to its higher temperature sensitivity.

1. Introduction

Soil organic matter represents an important carbon reservoir in the terrestrial biosphere. It is estimated that SOC is roughly double that of the atmosphere or aboveground vegetation (Schimel, 1995). In soils in alpine areas – as in other cold ecosystems – C stocks are particularly important, since low temperatures limit decomposer activity (Schlesinger and Andrews, 2000) and keep C immobilized in soils during long periods of time (Körner, 2003). The forecasted global climate change would have important effects on the SOM decomposition, and these effects are expected to be greater in soils in the coldest regions (Melillo et al., 2002). Changes in SOM decomposition rates could result in changes in biochemical cycles that would affect the structure and functioning of these ecosystems. Indeed changes in the structure and function of the ecosystems would alter carbon dioxide (CO_2) efflux from the soil into the atmosphere, provoking positive feedbacks, enhancing the greenhouse effect. Nevertheless, it is very uncertain whether ecosystems turn from a sink to a source – or vice versa – under climate change conditions, since several factors affect the net balance between C loss through SOM decomposition and C gain from primary productivity (Bardgett, 2005; Davidson and Janssens, 2006; Powlson et al., 2011).

SOM decomposition can be understood as a function of microbial community (in terms of microbial biomass and specific composition) and activity (decomposition), and their dependence on environmental factors. Such environmental factors are mainly soil moisture (Chen et al., 2000; Schimel et al., 1999), soil temperature (Bekku et al., 2004; Kirschbaum, 1995), and substrate quantity (Vance and Chapin, 2001) and quality (Nadelhoffer et al., 1991; Vance and Chapin, 2001). One issue of long debate is the effect of increasing temperatures on SOM decomposition, since microbial respiration is sensitive to temperature changes. Specifically, soils in cold ecosystems often show higher temperature sensitivity of SOM decomposition when compared with other ecosystems (Bekku et al., 2004), making them more vulnerable to the impacts of increasing temperature. However, the factors determining the temperature sensitivity of SOM decomposition are still under debate (Fierer et al., 2006; Vanhala et al., 2008). Existing research along altitudinal gradients showed controversial results with regard to the temperature sensitivity of SOM decomposition. Increases in temperature sensitivity have been observed with increasing elevation in soil and microbial respiration by Sjögersten and Wookey (2002), Kätterer

* Corresponding author.
E-mail address: algutier@ucm.es (A. Gutiérrez-Girón).

http://dx.doi.org/10.1016/j.geoderma.2014.08.005
0016-7061/

et al. (1998) and Niklińska et al. (1999); while other authors have reported higher temperature sensitivity at lower altitudes (Lipson, 2007), or found no differences between altitudes (Niklińska and Klimek, 2007; Schindlbacher et al., 2010). Although the knowledge of the environmental drivers of SOM decomposition in cold climate regions has improved in the last decade (e.g. Bekku et al., 2004; García-Pausas et al., 2008; Lipson, 2007; Lipson et al., 2000) little is known about SOM decomposition responses to environmental factors in Mediterranean high-mountain areas. Mediterranean ecosystems show particular environmental conditions, mainly driven by summer drought, that make their functioning different to temperate and cold ecosystems, and they may be particularly affected by climate warming due to temperature and rain pattern changes (Engler et al., 2011; Schröter et al., 2005).

High-mountain environments harbor ecosystems that are very sensitive and vulnerable to global changes (Schröter et al., 2005). Shrub encroachment has occurred in recent decades in several Iberian mountain areas (Molinillo et al., 1997; Roura-Pascual et al., 2005), even in the area surrounding the study site (Muñoz-Jiménez and García-Romero, 2004; Sánz-Elorza et al., 2003) due to land use and climate changes. Shrub encroachment into mesic grasslands in the Pyrenean mountains showed a slight increase in SOC stocks (Montané et al., 2007) related to a higher recalcitrance of shrub litter relative to grass litter (Montané et al., 2010). Nevertheless, the particular climate conditions of Mediterranean areas that cause the dominance of dry grasslands in the study area may give rise to different effects of vegetation changes on SOM decomposition to those reported in northern mountains (Jackson et al., 2002). We are not aware of any study assessing the effects of vegetation changes on SOM dynamics in Mediterranean high-mountain soils.

Altitudinal gradients in mountains are correlated with climate gradients and changes on vegetation communities. Therefore altitudinal shifts in SOM decomposition and its dependence on environmental factors make these comparisons useful for the assessment of climate- and vegetation-related impacts (Diaz et al., 2003; Niklińska and Klimek, 2007; Schindlbacher et al., 2010). The aim of this study is to evaluate the mechanisms responsible for differences in SOM decomposition patterns along an altitudinal gradient in Mediterranean high-mountains, involving both temperature shifts and changes in the vegetation community, as a proxy for detecting feedbacks due to climate change. Specifically, we evaluated the altitudinal shifts in SOC and total soil N, DOC and MBC. We also assessed the altitudinal shifts of microbial respiration, temperature sensitivity and C substrate limitation. Finally, we tested for differences in soil and microbial parameters between shrub and grassland vegetation to evaluate the potential effects on SOM decomposition patterns due to shrub encroachment in Mediterranean high-mountain grasslands. We hypothesized a decrease in SOM and therefore in SOC and soil N content with increasing altitude, as plant activity is expected to be more strongly limited by low temperatures than microbial activity (García-Pausas et al., 2007). Moreover, we expected a decrease in both microbial respiration and C availability with elevation (Fierer et al. (2009)). Additionally, we surmised that the soil microbial respiration in colder sites were more sensitive to temperature increases than those of warmer sites (Schindlbacher et al., 2010; Vanhala et al., 2008), and therefore Q_{10} of microbial respiration would increase with elevation. With regard to differences in shrub and grassland vegetation we hypothesized that – as proposed by Jackson et al. (2002) for dry plant communities – in shrubland vegetation, organic C pools were larger than in grasslands.

2. Materials and methods

2.1. Study site

The study was conducted in the Sierra de Guadarrama (40° 47′ N, 3° 57′ W), a mountain range located in Central Spain. Parent material of the area consists of siliceous plutonic and metamorphic rocks (i.e. granite and gneiss). The vegetation in the area is constituted by shrub communities of the broom *Cytisus oromediterraneus* Rivas Mart. et al. and dwarf juniper *Juniperus communis* subsp *alpina* (Suter) Čelak., and short and dry perennial grasses dominated by *Festuca curvifolia* Lag. ex Lange. Above the tree-line limit (1900–2000 m a.s.l.), both shrub and grass communities form a mosaic. Over 2200 m a.s.l, the vegetation is almost dominated by grasses of *F. curvifolia* accompanied by cushion plants. The soils at the sites are Umbrepts and Orthents under shrub communities, and Cryumbrets under high-mountain grassland communities (Hoyos et al., 1980).

At the nearest weather station (2.3 km away), located in the Navacerrada pass at 1890 m a.s.l., the mean annual temperature is 6 °C and annual precipitation is 1350 mm, with a slight dry period from May to October with less than 10% of the total annual rainfall. These Mediterranean high-mountain ecosystems can be under snow cover from late October to mid April; however, the snow cover length greatly varies between years as a consequence of varying Mediterranean climate conditions, and it often has a discontinuous duration during the winter due to the heterogeneous snow fall and wind effects. These ecosystems are also subjected to short growing seasons, low winter temperatures and strong winds.

2.2. Soil Temperature measurements

Soil temperatures under shrubland and grassland vegetation were assessed by means of temperature records from the GLORIA target region in the Sistema Central mountains (www.gloria.ac.at). We used the records from 16 temperature dataloggers (Geoprecision M-log5W) buried at 10 cm depth and distributed in the four main compass directions (Pauli et al., 2004) on four summits in the Sierra de Guadarrama mountains ranging from 2100 to 2280 m a.s.l. In order to assess the soil temperature conditions, we calculated mean annual temperature, mean temperature of the coldest month and mean temperature of the warmest month using soil temperature records of 2008 and 2009. The temperature records of two extra dataloggers installed at a depth of 10 cm in the highest site (i.e. 2380 m a.s.l.) were used to calculate the soil temperature variation linked to the altitudinal gradient.

2.3. Sampling collection

To assess altitudinal shifts on SOM decomposition we collected samples in early July 2009 at four different altitudes along an altitudinal gradient (i.e., 2100, 2200, 2300 and 2380 m a.s.l.). At each altitudinal level, six 1×1 m^2 plots with a well-developed vegetation cover were selected. Inside each plot we randomly collected one soil block of $10 \times 10 \times 10$ cm^3 for measurements of soil parameters and microbial activity.

To compare the vegetation effect (grasses vs shrubs) on soil and microbial parameters we collected mineral soil samples under *C. oromediterraneus* shrubs in sites at 2100 m a.s.l. and 2200 m a.s.l. where this type of vegetation was present. We randomly selected six shrub individuals of *C. oromediterraneus* close to each of the 1×1 m^2 plots of grassland previously sampled (6 shrubs for each altitude and 12 in total). One soil block sample of $10 \times 10 \times 10$ cm^3 was collected closer to the center of each individual shrub, under each of the 12 shrubs.

After collection, all the soil samples were kept cold during transportation to the laboratory. Soil samples were passed through a 2 mm-sieved, roots were manually removed and a sufficient quantity of soil samples was preserved frozen at −20 °C until further analyses. Prior to microbial measurements started, soil samples were thawed during 24 h at 5 °C.