Global and Planetary Change 133 (2015) 87–95

Contents lists available at ScienceDirect

Global and Planetary Change

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

Glomalin accumulated in seagrass sediments reveals past alterations in soil quality due to land-use change

Lourdes López-Merino [a,*], Oscar Serrano [b,c], María Fernanda Adame [d], Miguel Ángel Mateo [b,e], Antonio Martínez Cortizas [f]

[a] Institute of Environment, Health and Societies, Brunel University London, Uxbridge UB8 3PH, UK
[b] Centre for Marine Ecosystems Research, Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027, Australia
[c] UWA Oceans Institute, University of Western Australia, 35 Stirling Highway, Crawley 6009, Australia
[d] Australian Rivers Institute, Griffith University, 170 Kessels Road, Nathan, QLD 4111, Australia
[e] Centro de Estudios Avanzados de Blanes, Consejo Superior de Investigaciones Científicas, Acceso a la Cala S. Francesc 14, 17300 Blanes, Spain
[f] Departamento de Edafología y Química Agrícola, Facultad de Biología, Universidad de Santiago de Compostela, Campus Sur, 15782 Santiago de Compostela, Spain

ARTICLE INFO

Article history:
Received 20 February 2015
Received in revised form 25 July 2015
Accepted 4 August 2015
Available online 5 August 2015

Keywords:
Glomalin-related soil protein
Posidonia mat
Land-use change
Palaeoecological proxy
Soil quality

ABSTRACT

Arbuscular mycorrhizal fungi (AMF), symbionts with most terrestrial plants, produce glomalin-related soil protein (GRSP), which plays a major role in soil structure and quality. Both fungi hyphae and protein production in soils are affected by perturbations related to land-use changes, implying that GRSP is a sensitive indicator of soil quality. Unfortunately, GRSP degrades within years to decades in oxic environments, preventing its use as palaeoecological proxy. However, GRSP is transported to marine, near-shore anoxic sediments, where it accumulates and remains non-degraded, enabling the assessment of its potential as a palaeoecological proxy for soil ecosystem's health. Exploiting this fact, we have obtained for the first time a long-term record (c. 1250 years) of GRSP content using a *Posidonia oceanica* seagrass mat sediment core from the Western Mediterranean (Portlligat Bay, Spain). The trends in GRSP content matched well with land-use changes related to agrarian activities reconstructed by pollen analysis. In periods of cultivation, GRSP accumulation in the mat decreased. Given the role played by GRSP, the results suggest that agrarian intensification may have resulted in perturbations to soil quality. Thus, GRSP in seagrass mat sediments can be used to assess long-term trends in continental soil quality induced by human activities. These findings open new possibilities in long-term ecology research, as other anoxic environments could be potentially valid too. Testing them would open the possibility to identify long-term patterns in soil quality and other environmental stressors that could also affect AMF and GRSP production in soils.

1. Introduction

Unravelling the potential of new palaeoecological proxies providing information on when a system has been disturbed is challenging. Past changes in land-use, i.e., agrarian practices, can be tracked back in time using palaeoecological techniques. Alterations in forest cover, hydrology and trophic status, as well as soil erosion, are the environmental consequences associated with the establishment of crops that are typically reconstructed in palaeoecological and palaeoenvironmental research (Dearing et al., 2006). However, other transformations that can be identified in present landscapes have passed unnoticed in the palaeoecological record, even when they could be useful to detect long-term variations in soil quality due to land-use change. One of them is the alteration of hyphae production by arbuscular mycorrhizal fungi (AMF), which are symbionts with the roots of most terrestrial plants and play a significant role in soil ecosystems' functioning (Wright et al., 2006).

Glomalin-related soil protein (GRSP) is a recently discovered glycoprotein produced by AMF (Gadkar and Rillig, 2006). GRSP is a significant component of soil organic matter, playing an important role in nitrogen and carbon storage and turnover, soil aggregate stability and soil texture (Rillig and Steinberg, 2002; Rillig et al., 2001; Staddon et al., 2003; Wright and Upadhyaya, 1998). Concentrations of GRSP in soils have been linked to land-use change, indicating that its abundance responds to ecosystems' modifications. In the Delaware Wildlife Area (Ohio, US), agricultural (corn and soybean) and afforested soils had lower GRSP concentrations than native temperate deciduous forest soils (Rillig et al., 2003). The conversion of Mexican rainforest to pasture and agricultural land (corn and common bean) decreased soil GRSP concentrations (Violi et al., 2008). In soils from south Cameroon GRSP content declined from forest to fallow and field crops (groundnuts, corn cassava,

* Corresponding author.
E-mail address: lourdes.lopez-merino@brunel.ac.uk (L. López-Merino).

http://dx.doi.org/10.1016/j.gloplacha.2015.08.004
0921-8181/

plantain; Fokom et al., 2012). As land-use alters AMF communities, affecting GRSP production and its soil concentration (Wright et al., 1999), it is considered that the more GRSP in a soil the better the soil quality (Shrestha Vaidya et al., 2011), hence providing information on the health of a given soil ecosystem.

GRSP has a turnover time of years to decades in well-aerated soils (Rillig et al., 2001). Since it rapidly degrades with time in oxic environments, most terrestrial soils are not effective environmental archives for the reconstruction of long-term GRSP trends, preventing the use of GRSP as a palaeoecological proxy. However, GRSP has been detected in superficial sediments of intertidal *Posidonia australis* seagrass meadows and wetlands, and coastal coral reefs (Adame et al., 2010, 2012). Although AMF colonise most terrestrial plants' roots, the ability of AMF to colonise plants' roots is limited by salinity (Adame et al., 2012), and AMF colonisation of seagrass roots has not been observed (Nielsen et al., 1999). The GRSP produced by AMF is found outside of the fungal structures, indicating it is transferred to the environment (Driver et al., 2005). GRSP can leach or be washed from soils into streams, and it is detected downstream in floodplains and rivers (Harner et al., 2004). Rivers and groundwater transport terrestrial material containing GRSP that is deposited in accretion areas and coastal systems, evidencing a terrestrial-marine connectivity (Adame et al., 2010, 2012). The highly anoxic conditions of marine environments, such as seagrass sediments, would prevent the degradation of GRSP enabling the reconstruction of long-term records of GRSP change.

The GRSP found in the coastal marine environment is likely to reflect landscape-scale processes, as it is not produced locally and has been transported by watershed runoff towards the sea (Adame et al., 2012; Harner et al., 2004). Thus, it is worth comparing synchronous terrestrial landscape changes and variations in GRSP content in marine sediments. For this purpose, palynological studies provide landscape-scale information on when an area was transformed and the magnitude of that transformation. This comparison would allow the assessment of whether changes in GRSP content in marine sediments could be linked to terrestrial landscape changes (i.e., land-use change).

In this study we report the last c. 1250 years of changes in GRSP content, detected in a Western Mediterranean seagrass *Posidonia oceanica* mat core (Portlligat bay, Spain, Fig. 1). The GRSP record is compared with landscape vegetation changes, including agriculture indicators, obtained from a previous palynological study performed on the same mat core (López-Sáez et al., 2009) (see Supplementary Information). Fluctuations in GRSP content in the seagrass mat and in terrestrial landscape composition and structure inferred by pollen data (i.e., turnover, PCA results, richness and evenness) were characterised using change-point modelling (Gallagher et al., 2011) to statistically detect synchronous events. The goal was to evaluate whether GRSP accumulated in coastal anoxic environments could be used as a palaeoecological proxy and to assess whether long-term GRSP variations in coastal environments accurately reflect soil alterations in quality related to past changes in land-use.

2. Methods

2.1. Study site and sampling

The Portlligat Bay (42°17′32″ N; 3°17′28″ E) is a small (0.14 km^2) and shallow (<10 m deep) inlet located in NE Spain, in the Cape Creus, connected to the sea through a 213 m wide opening to the NW (Fig. 1). Living meadows of *P. oceanica* cover about 68% of the bottom of the bay. The bay receives freshwater input from a typical Mediterranean temporary stream that flows into it from its NE shore. The Cape Creus itself (eastern Pyrenees) is a geological formation originated 400 million years ago. This area presents a Mediterranean climate, with warm summers, mild winters and summer drought. The landscape has had an intense human fingerprint for a long time. Traditional activities, such as dry-land farming and fisheries, have been replaced by tourism, leaving the area occupied by abandoned terraced vineyards and pasturelands. Mediterranean scrubland dominated by *Pistacia lentiscus*, *Juniperus oxycedrus*, *Calicotome spinosa* and species of *Erica* and *Cistus* are important. Forest cover is sparse, with *Pinus halepensis* and *Quercus suber* as the most abundant tree species, while in sheltered areas *Quercus ilex* and *Quercus pubescens*, and in riparian areas *Ulmus minor*, *Fraxinus angustifolia*, *Alnus glutinosa*, *Corylus avellana* and *Salix* sp. appear (Franquesa I Codinach, 1995).

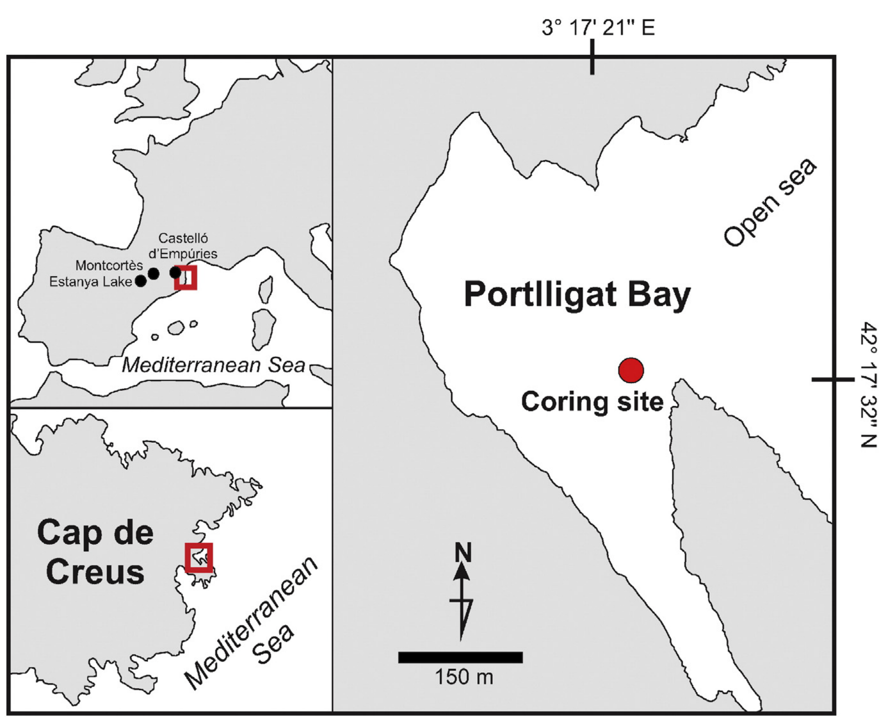

Fig. 1. Location of the drilling point of core 2000 in the *P. oceanica* bed at the north-western part of the Mediterranean Sea (Portlligat Bay, Cape Creus, Spain). Other sites cited in the text are also located in the map.