Quaternary International xxx (2016) 1–9

Contents lists available at ScienceDirect

Quaternary International

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

Potential of soil phytoliths, organic matter and carbon isotopes for small-scale differentiation of tropical rainforest vegetation: A pilot study from the campos nativos of the Atlantic Forest in Espírito Santo State (Brazil)

Marcia Regina Calegari [a], Marco Madella [b, c, *], Lucas Tagliari Brustolin [a], Luiz C. Ruiz Pessenda [d], Antonio A. Buso Jr. [d], Mariah I. Francisquini [d], José A. Bendassolli [e], Pablo Vidal-Torrado [f]

[a] Department of Geography, West Paraná State University — UNIOESTE, Rua Pernambuco, 1777, Caixa Postal 91, CEP 85970-020, Mal. Cd. Rondon, Paraná, Brazil
[b] ICREA — CaSEs, Department of Humanities, Universitat Pompeu Fabra, C/Trias Fargas 25, 08005 Barcelona, Spain
[c] IMF — Spanish National Research Council (CSIC), C/Egipciaques 15, 08001 Barcelona, Spain
[d] ^{14}C Laboratory, Centre for Nuclear Energy in Agriculture (CENA), University of São Paulo, Avenida Centenário 303, CEP: 13400-000 Piracicaba, SP, Brazil
[e] Centre for Nuclear Energy in Agriculture (CENA), University of São Paulo, Avenida Centenário 303, 13400-000 Piracicaba, SP, Brazil
[f] Department of Soil Science, ESALQ, University of São Paulo, Avenida Pádua Dias, 11, 13418-260 Piracicaba, SP, Brazil

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Phytoliths
Organic matter
C isotopes
Spodosol
Atlantic Forest
Grasslands

ABSTRACT

A truthful vegetation reconstruction is essential for understanding the historical trajectory of climate change and as well as the nature and extent of human impact on ecosystems. A classical approach to these studies is the use of pollen to identify flora composition and variability over time. However, the use of pollen is not always viable due to lack of depositional environments and general taphonomic processes, such as edaphic conditions. The most durable plant fossils, with widespread presence in diverse depositional realities, are phytoltihs. These proxies are common, well preserved in soils and with great potential for the detection of vegetation signals at micro and meso-level. Therefore, phytoliths are an important tool for recognising variability in major biomes such as tropical forests. In this study we illustrate the results of a pilot project in the Atlantic Forest (Mata Atlântica) of Brazil. The Atlantic Forest is a very diverse ecosystem and its environmental history is still poorly known, especially in relation to the origin and development of non-forested islands (campos nativos) within the forest. Campos nativos create a mosaic with the Mata Atlântica and their current persistence is due to a combination of topographic effects, hydrology and soil. Our work evaluated the potential of soil phytolith, total organic content (TOC) and δ^{13}C of two grassland/savannah campos nativos in the Vale Nature Reserve in Linhares (state of Espírito Santo). The results from isotopic analysis show the relevance of C3 plants since the beginning, and for all the sedimentary history, in both campos nativos. The soils of the nativos are spodosols and, surprisingly, the phytolith composition has been drastically affected by the edaphic conditions. The phytolith assemblages are often impoverished, especially in the soil sandy layer. However, the assemblages still show an important local floristic component (micro scale) with an input from the surrounding vegetation (meso-scale).

1. Introduction

The truthful reconstruction of vegetation is essential for understanding historical trajectories of climate change, and to address the nature and extent of anthropic impact on the ecosystems. A classical approach to this study is the use of fossil

* Corresponding author. ICREA - CaSEs, Department of Humanities, Universitat Pompeu Fabra, C/Trias Fargas 25, 08005 Barcelona, Spain.
E-mail address: marco.madella@icrea.cat (M. Madella).

http://dx.doi.org/10.1016/j.quaint.2016.01.023
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pollen to identify past floristic composition and its variation over time (Moore et al., 1994). The preservation of pollen is however restricted to the presence of suitable depositional environments (e.g. lakes, peat bogs, etc) (Van Mourik, 2001). Furthermore, the fossil pollen assemblages from Neotropic forests do not represent an ideal analogue match with present-day pollen rain (Gosling et al., 2009), thus creating further interpretative problems. On the other hand, soils are ubiquitous terrestrial sediments and represent a major reservoir for climatic proxies, both physico-chemical and biological. Furthermore, the use of proxies that can detect local signals (at micro or meso-level) is important for detecting vegetation variability within major biomes, such as the tropical rainforests.

Within soils is preserved one of the most durable plant micro-fossil with the potentials for detecting micro and meso-level signals: phytoliths (opal silica particles deposited in and between cells in plant tissues). Indeed, phytoliths from soils and palaeosols have been successfully used to reconstruct past climate and vegetation in many tropical regions (to cite a few: Guillet et al., 1988; Alexandre et al., 1999; Freitas et al., 2001; Wooller, 2002; Bremond et al., 2005; Neumann et al., 2009; Iriarte et al., 2010; Dickau et al., 2013; Watling and Iriarte, 2013) and a few examples relate to the Neotropics (e.g. Kondo and Iwasa, 1981; Piperno and Becker, 1996; Alexandre et al., 1999; Borba-Roschel et al., 2006; Calegari et al., 2013; Coe et al., 2013).

Furthermore, the use of carbon isotopes (δ^{13}C) in studies of soil organic matter dynamics has been used in many tropical areas (and Brazil as well) to document Holocene vegetation changes (i.e., ratio of C3 and C4 plants) (Volkoff and Cerri, 1987; Freitas et al., 2001; Pessenda et al., 2001a,b, 2004, 2005, 2009).

Tropical rainforests, which are present in widely separated areas, show evidences of noticeable resemblances among the formations. They are composed of analogous trees communities with homogeneous characteristics and tend to show great similarity in their spatial arrangement (Richards, 1971). Species of corresponding communities in different geographical regions are, to a considerable degree, alike in physiognomy. The fundamental pattern of structure is thus the same throughout the whole extent of a rain forest. However, several studies highlights differences at meso and micro-levels that, considering a relatively uniform climate, are due to changes in topography, hydrology and soil types (Richards, 1971; Singh, 1974; He et al., 1996). This clearly results in an important rainforests feature: high variability within small areas and relative uniformity over large areas. It is the pattern of meso- and micro-variation that interests the current study and especially the possibility to identify, through vegetation proxies such as phytoliths and carbon isotopes, this variability for investigating the evolutionary trajectories of tropical rainforests.

In this work we present a pilot study to assess the potentials of soil phytolith, total organic carbon content and δ^{13}C from grassland vegetation (locally called *campos nativos*) existing in the tropical rainforest (Atlantic Forest) of the northern coast of Espírito Santo State, south-eastern Brazil.

The campos nativos create a mosaic with the Atlantic Forest, a pluvial forest of the Atlantic coast of Brazil (IBGE, 1987) (Fig. 1), and their persistence is due to a combination of topographical, hydrological and soil effects. The Atlantic Forest is a very diverse ecosystem (Morellato and Haddad, 2000; Oliveira-Filho and Fontes, 2000) that is credited to a rich flora with unique physiological adaptations to unusual biophysical characteristics (Garcia and Pirani, 2005). Regardless of the tremendous biological importance of this Neotropic biome, its environmental history is still poorly known, and especially the origin and development of non-forested islands (the *campos nativos*) within this forest. The climatic characteristics of the lowland Atlantic forest are high insolation rates, with annual temperatures averaging 25 °C, and high humidity (between 1100 and 1500 mm of precipitation).

2. Regional setting

The study area is part of the Vale Nature Reserve (Fig. 1), a protection area within the natural range of the lowland Atlantic Forest. The Vale Nature Reserve is located 30 km north of the Doce River, between Linhares and Jaguaré in the north of the Espírito Santo State. The reserve is part of the Atlantic Forest central corridor, and it is one of the most important areas for biodiversity conservation (Ministério do Meio Ambiente, 2000). It has ca.

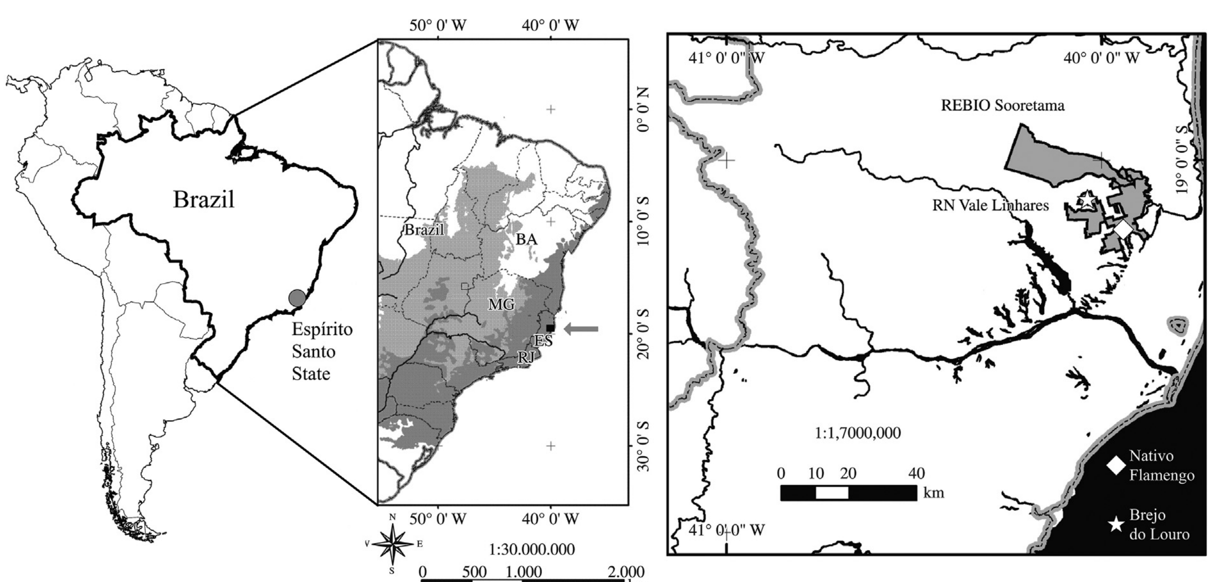

Fig. 1. Map showing the approximate position of the Nativo Flamengo and Brejo do Louro in the Vale Nature Reserve, north of Espírito Santo State (Brazil). Modified from Nemésio (2013).

Please cite this article in press as: Calegari, M.R., et al., Potential of soil phytoliths, organic matter and carbon isotopes for small-scale differentiation of tropical rainforest vegetation: A pilot study from the campos nativos of the Atlantic Forest in Espírito Santo State (Brazil), Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2016.01.023