Palaeogeography, Palaeoclimatology, Palaeoecology 415 (2014) 59–68

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Understanding Holocene variations in the vegetation of Sao Joao River basin, southeastern coast of Brazil, using phytolith and carbon isotopic analyses

Heloisa H.G. Coe [a], Kita Macario [b,*], Jenifer G. Gomes [a,b], Karina F. Chueng [a], Fabiana Oliveira [b], Paulo R.S. Gomes [b], Carla Carvalho [b,c], Roberto Linares [b], Eduardo Alves [b], Guaciara M. Santos [d]

[a] Universidade do Estado do Rio de Janeiro, São Gonçalo, RJ, Brazil
[b] Universidade Federal Fluminense, Niteroi, RJ, Brazil
[c] Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brazil
[d] University of California, Irvine, CA, United States

ARTICLE INFO

Article history:
Received 31 May 2013
Received in revised form 9 January 2014
Accepted 18 January 2014
Available online 25 January 2014

Keywords:
Radiocarbon
Phytolith
^{14}C-AMS

ABSTRACT

To understand variations in the vegetation of the southeastern coast of Brazil during the Holocene and to identify roughly when they took place, we make use of phytolith morphology and carbon stable isotope analyses coupled with ^{14}C dating of soil profiles. The soil profile studied is located in the Sao Joao River Basin close to Cabo Frio, Rio de Janeiro State. We evaluated the soil characteristics, which showed great variations in granulometry, with larger texture in upper horizons that enabled the movement of particles to lower layers. The accumulation soil horizons revealed several palaeoclimatic aspects: higher phytolith stocks, a higher density of trees, and a lower water stress at the bottom of the profile, and a predominance of C3 grasses throughout the Holocene. Carbon stable isotopic ratios of the soil profile confirm the predominance of C3 plants, except for E/Bt horizon which was enriched in ^{13}C. The soil organic matter mean residence time ranges from post-bomb (topsoil) to 10,245 years cal BP at the base of the profile. The results of this study are compatible with other evidence of a more humid environment in the first half of the Holocene.

1. Introduction

The Brazilian Southeast was formerly occupied by Atlantic forest before the arrival of Europeans in the 16th century, when deforestation slowly started to take place. This region has undergone important climatic oscillations during the Quaternary (e.g. Ledru et al., 1998; Marchant and Hooghiemstra, 2004; Cruz et al., 2005, 2006; Wanner et al., 2008; Wanner and Brönnimann, 2012; Buso et al., 2013).

The Sao Joao River basin, originally within the Atlantic forest biome, is an area that is still poorly studied in terms of its landscape and soil profile evolution. Although most of the original Atlantic forest vegetation has been lost, some information can still be obtained from the study of phytoliths deposited in soil layers.

Phytoliths are microscopic particles formed as a result of absorption of dissolved silicon (Si) from soils by roots, followed by deposition and biomineralization. These biosilica structures can be found inside the cells of many living plants. Furthermore, they are usually found within the finest sand fractions, where the whole plant or tissue parts have decayed (Piperno, 1988). After being recovered from soils, these microfossils show configurations that can be associated with their original vegetation. Phytoliths can be classified by taxonomy or by their physical characteristics, and they are generally studied by analyses of their assemblages.

After phytolith morphotypes are identified, calculation of phytolith indices helps track some important environmental parameters, such as density of trees, adaptation to drought, or water stress (Fredlund and Tieszen, 1994; Bremond et al., 2005a,b; Messager et al., 2010; Coe et al., 2012). Even though some phytoliths can percolate downwards through the soil profile, statistical analysis of phytolith assemblages can still provide valuable information on the vegetation patterns. As Krauss et al. (1997) pointed out, as long as the soil composition is relatively uniform with depth, it is safe to assume that the percolation rate for a given phytolith morphotype will not vary significantly.

Stable isotopes of carbon (^{12}C and ^{13}C) can also be used as a proxy of biological processes in plants. Carbon isotopic discrimination during photosynthesis provides insight into photosynthetic

* Corresponding author. Tel.: +55 2126 295 892.
E-mail address: kita@mail.if.uff.br (K. Macario).

0031-0182/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.palaeo.2014.01.009

metabolism in plants as well as its environmental influences. For instance, plants that utilize the Calvin–Benson photosynthetic pathway, which tends to prefer the lighter isotope, are referred to as C3 and have $\delta^{13}C$ values from −32 to −22‰. The C4 plants use the Hatch–Slack cycle and have $\delta^{13}C$ values in the range of −9 to −17‰ (Gleixner, 2002; Gordon and Goñi, 2003; Killops and Killops, 2005). Consequently, the $^{13}C/^{12}C$ ratio in soil organic matter (SOM) should remain close to the ratio of the original vegetation. However, due to organic matter (OM) heterogeneity in soils and sediments, $\delta^{13}C$ values will depend on the OM original sources (Hedges and Parker, 1976). In forest ecosystems $\delta^{13}C$ values of soil OM (SOM) are generally less negative than the source vegetation. Studies show an increase of 1 or 2‰ during decomposition of vegetable tissues (Martinelli et al., 2009).

Information regarding palaeovegetation changes can ultimately be related to its possible time of occurrence by radiocarbon (^{14}C) dating of SOM. Although charcoal fragments and humin are the most appropriate fractions for dating SOM (Pessenda et al., 2001), the lack of sufficient amounts in some cases has been forcing researchers to rely on ^{14}C dates obtained on total SOM. Because SOM is composed of a complex mixture of OM of different origins in various stages of decomposition, its age is normally significantly younger than dates obtained from more stable organic compounds found in soil (Pessenda et al., 2001). Therefore, its bulk ^{14}C age can only represent a mean residence time (MRT) of the OM in the soil sample (Martin and Johnson, 1995) and should be interpreted with caution. Because the pool of OM in some soils can also be very scarce, MRT is normally obtained by the ^{14}C method performed by the accelerator mass spectrometry (AMS) technique. The MRT ages of SOM are then assumed to be the minimum mean ages of phytolith assemblage deposition in these soils.

In order to better understand the variations in the vegetation of Sao Joao River basin during the Holocene, we performed phytolith and carbon stable isotope analyses coupled with ^{14}C dating of total SOM samples.

2. Study area

The Sao Joao River basin is located between 22°20′ and 22°50′ S and 40°00′ and 42°40′ W, covering a surface of 2160 km^2 and a perimeter of 266 km. Eight counties constitute the basin: Cachoeiras de Macacu, Rio Bonito, Casimiro de Abreu, Araruama, Sao Pedro da Aldeia, Cabo Frio, Rio das Ostras and Silva Jardim (Bidegain, 2005) (Fig. 1).

This region features a humid tropical climate, with precipitation concentrated during the summer (average annual rainfall of 2000 mm) and a mean annual temperature of 25.5 °C (Cunha, 1995).

In the past, the region was covered by a lowland rain forest with high altitude grasslands lining the mountains, the plateau and the hills. However, continuous deforestation for logging and/or farming reduced the long and continuous extension of tropical forest to isolated fragments of vegetation surrounded by areas of agriculture. The current basin landscape consists mostly of cleared fields and secondary forests, alluvial forests, and forested hills. Nowadays, the land in the basin is subdivided for use as cities, farmland, and pastures, and it contains different types of vegetation, such as forests, swamps, altitude fields,

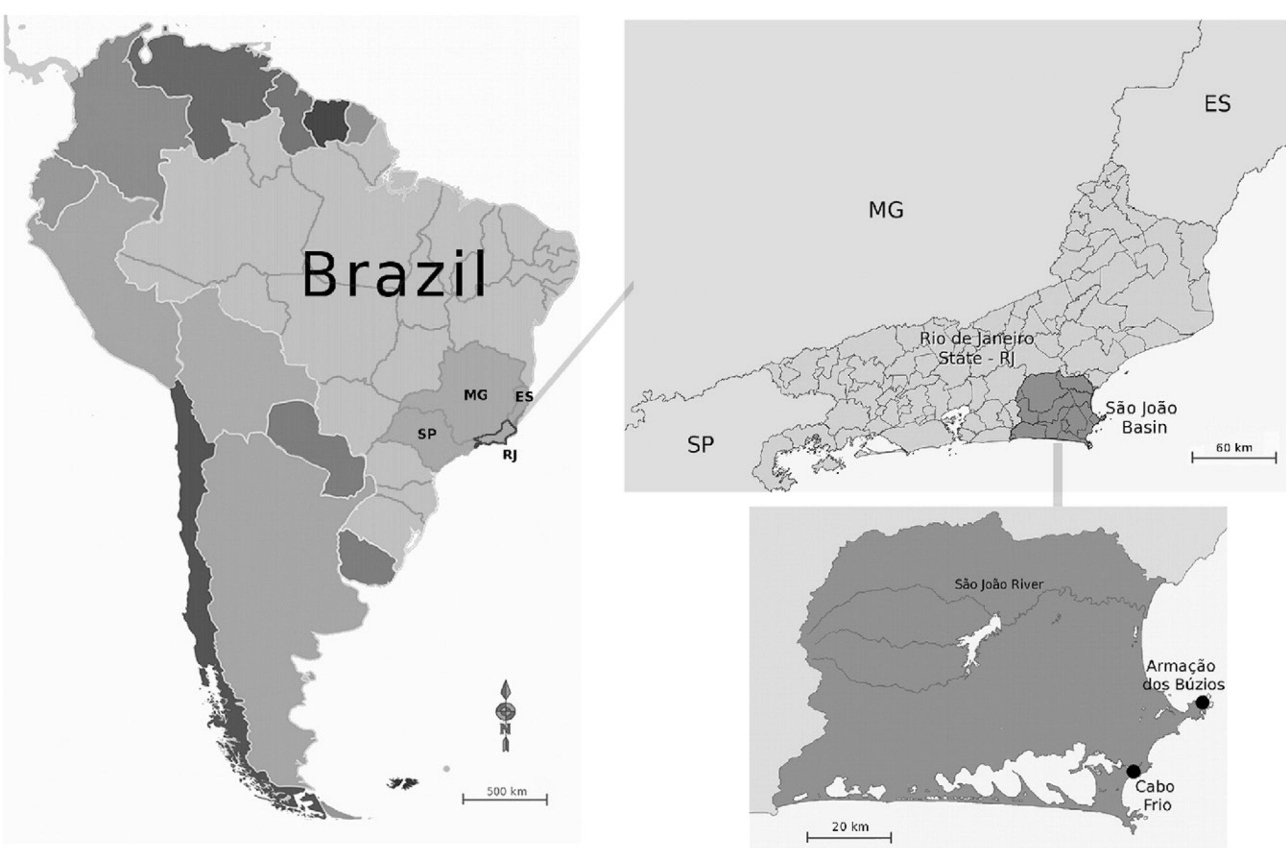

Fig. 1. Sao Joao hydrographic basin map, with cities.
Source: modified from Consórcio Intermunicipal Lagos São João, 1999) in http://www.micoleao.org.br/arquivos/mapas/bacia_sao_joao.jpg.