Review of Palaeobotany and Palynology 160 (2010) 53–65

Contents lists available at ScienceDirect

Review of Palaeobotany and Palynology

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

Araucaria forest dynamics in relation to fire frequency in southern Brazil based on fossil and modern pollen data

Vivian Jeske-Pieruschka [a,*], Alessandra Fidelis [b], Rodrigo S. Bergamin [c], Eduardo Vélez [c], Hermann Behling [a]

[a] Department of Palynology and Climate Dynamics, Albrecht-von-Haller-Institute for Plant Sciences, University of Göttingen, Untere Karspüle 2, 37073 Göttingen, Germany
[b] Laboratory of Landscape Ecology and Conservation, Department of Ecology, Universidade de São Paulo, Rua do Matão, Trav. 14, no. 321, 05508-900, São Paulo, Brazil
[c] Programa de Pós-Graduação em Ecologia, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500 Porto Alegre, RS, 91540-000, Brazil

ARTICLE INFO

Article history:
Received 28 July 2009
Received in revised form 28 December 2009
Accepted 18 January 2010
Available online 25 January 2010

Keywords:
late Holocene
Araucaria forest
Campos-grassland
fire
human impact
pollen analysis

ABSTRACT

To elucidate the relationship between forest dynamics and fire frequency pollen percentages and charcoal amounts from a 120 cm long peat core and from samples of modern pollen rain were collected along a transect. The study site in southern Brazil is characterized by a species-rich mosaic of grassland–*Araucaria* forest. It is of crucial importance for management strategies for conservation to understand the development and maintenance of these vegetation mosaics including their sharp forest–grassland boundaries. During the late Holocene, considerable changes occurred in the area. From Anno Domini (AD) 1360 to 1410, the area was dominated by Campos (grassland) vegetation and fire was very common. From AD 1410 to 1500, *Araucaria* forest expanded and fire was less frequent. From AD 1500 to 1580, Campos grassland spread and the *Araucaria* forest ceased its development, apparently due to the increase of fire. From AD 1580 to 1935, after a decrease in fire frequency, *Araucaria* forest expanded again. From AD 1935 to the present, the *Araucaria* forest expanded while the Campos area decreased. Fire was very rare in this period. The results indicate a strong interaction of forest expansion, forming a mosaic of Campos and *Araucaria* forest, and the frequency of fire during the past 600 years. A possible collapse of the indigenous population following the post-Colombian colonization in southern Brazil after about AD 1550 may have caused a great reduction of fire frequency. The introduction of cattle (probably after AD 1780) and the resulting decrease of fire frequency might be the reason for forest expansion. Fire is probably the most important factor controlling the dynamics of the forest–grassland mosaics and the formation of sharp borders between these two vegetation types.

1. Introduction

Nowadays, the southern highland region of Brazil is covered by a mosaic of grassland–forest vegetation, which is considered part of the Atlantic Forest Biome (IBGE, 2004). This peculiar vegetational formation is basically shaped by a mosaic of grassland, so-called Campos, and *Araucaria* forest with its distinct sharp boundary. Pillar and Quadros (1997) and Pillar (2003) affirmed that the natural vegetation mosaic of Campos–*Araucaria* forest in southern Brazil, including its boundaries, might be determined by grazing and fire regimes. Thus, palaeoenvironmental studies are important tools for confirming such affirmation. Knowledge of early fire activity is relatively well documented for the southern Brazil highlands where present day vegetation is still a mosaic of Campos and forest (Behling, 1997; Behling et al., 2007). Charcoal record from the last 42,840 yr BP documents that natural grassland fires were rare during the glacial periods. Frequent fires during the mid Holocene, as well as the expansion of *Araucaria* forests together with lower fire frequencies during the late Holocene are good indicators of anthropogenic fire (Behling et al., 2004). The reduction of fire after 500 yr BP in the tropical Americas is synchronous with the indigenous population collapse following European conquest (Nevle and Bird, 2008). The landscape of grassland–forest mosaic in the southern Brazil uplands has been under human influence, first by pre-Columbian cultures using slash and burn activity. After the 19th century, European settlers caused deforestation due to intense colonization.

According to Behling (1993, 1995, 1998, 2002) Campos covered extensive areas on the highlands of southern Brazil during the last glacial until mid Holocene times, when *Araucaria* forest began to expand through migration from gallery forests along rivers and wetlands since ca. 3210 cal yr BP. A pronounced expansion of the *Araucaria* forest is reported for about 1400 cal yr BP in Paraná state (Behling, 1997, 2007) and for about 1000 cal yr BP in Santa Catarina state (Behling, 1995). In Rio Grande do Sul state, the initial expansion occurred about 4320 yr BP, being more pronounced since 1100 cal yr BP (Cambará do Sul record, Behling et al., 2004; Behling and Pillar, 2007). However, the history of the origin and dynamics of the *Araucaria* forest and Campos mosaic ecosystems is still not completely

* Corresponding author. Tel.: +49 551 39 12421; fax: +49 551 39 8449.
E-mail address: vjeske@uni-goettingen.de (V. Jeske-Pieruschka).

0034-6667/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.revpalbo.2010.01.005

understood. Despite the very humid climate of present times, which favors replacement of grassland by forest, natural patches of grassland still exist within the forest area (Oliveira and Pillar, 2004; Overbeck et al., 2007). The reason for the sharp boundaries observed between the forest and grassland is also unclear. Therefore, past human activities and their possible role in the formation of Campos–*Araucaria* forest mosaics can be explored by applying both pollen and charcoal analyses.

Studies of late Quaternary palaeoenvironments of southern Brazilian highlands using palynological analysis have been published during the last few years (Behling and Pillar, 2007; Behling et al., 2001, 2004). However, studies using modern pollen rain data to help interpret fossil pollen records are lacking for the region. Surface soil samples collected along a transect through Campos vegetation and *Araucaria* forest can provide useful information on the interpretation of fossil pollen records from the same locality. Thus, changes in present and past vegetation are reflected in the pollen spectra. A floristic inventory can help to interpret pollen content in surface soil samples of the local area, which can indicate the presence of taxa in the area, or even their arrival from other areas. Surface samples data combined with core analysis are useful for interpreting modern vegetation in detail (Wright, 1967). Some authors have used modern pollen spectra to assist the interpretation of fossil pollen records e.g. in the Pampa grassland in Argentina (Stutz and Prieto, 2003), in Colombian Amazonas (Berrío et al., 2003) and in neotropical ecosystems of Bolivia (Gosling et al., 2009). Behling et al. (1997) investigated modern pollen rain in the lowlands of southern Brazil to determine the pollen spectra of the local vegetation (Atlantic rain forest). Behling et al. (2001) used modern pollen from surface samples from São Francisco de Paula region, but they analyzed only 8 surface samples without any floristic inventory. Consequently, the necessity of studies including fossil pollen records and modern pollen combined with floristic inventories for the southern Brazil Campos is highlighted.

The aim of this study is to describe the origin and dynamics of the *Araucaria* forest during the early Holocene until present using palynological methods. This study also intends to investigate the relationship between fire frequency and forest expansion. Another significant aspect is to understand how the sharp borders between Campos and forest arise and which factors control and maintain them. Knowledge about the development and maintenance of these mosaics is essential for conservation management of these species-rich ecosystems of the Atlantic rain forest.

2. Environmental setting

2.1. Study area and climate

The study area is situated in the northeastern highlands of the southernmost state of Brazil, Rio Grande do Sul (28°56′16″, 50°02′ 39.9″W) at a distance of approximately 9 km from the escarpment of the Serra Geral mountains range (Fig. 1). In geomorphological terms, it corresponds to the "Planalto Meridional". The studied peat bog is at 1050 m a.s.l., with a diameter of ca. 30 m at the border of a disturbed *Araucaria* forest island, surrounded by Campos. The special position of the bog in relation to these vegetation types offers an excellent opportunity to investigate the origin, dynamics and stability of this *Araucaria* forest island including human activities.

The climate on the highlands of Rio Grande do Sul is classified by Moreno (1961) as subtropical humid (Cfb, Köppen). It is characterized by rainfall distributed throughout the year and temperatures lower than 22 °C in the warmest month and higher than 3 °C in the coldest month. The South Atlantic Anticyclone and the Polar Anticyclone with its origin in the Antarctic and its trajectory over the South-American

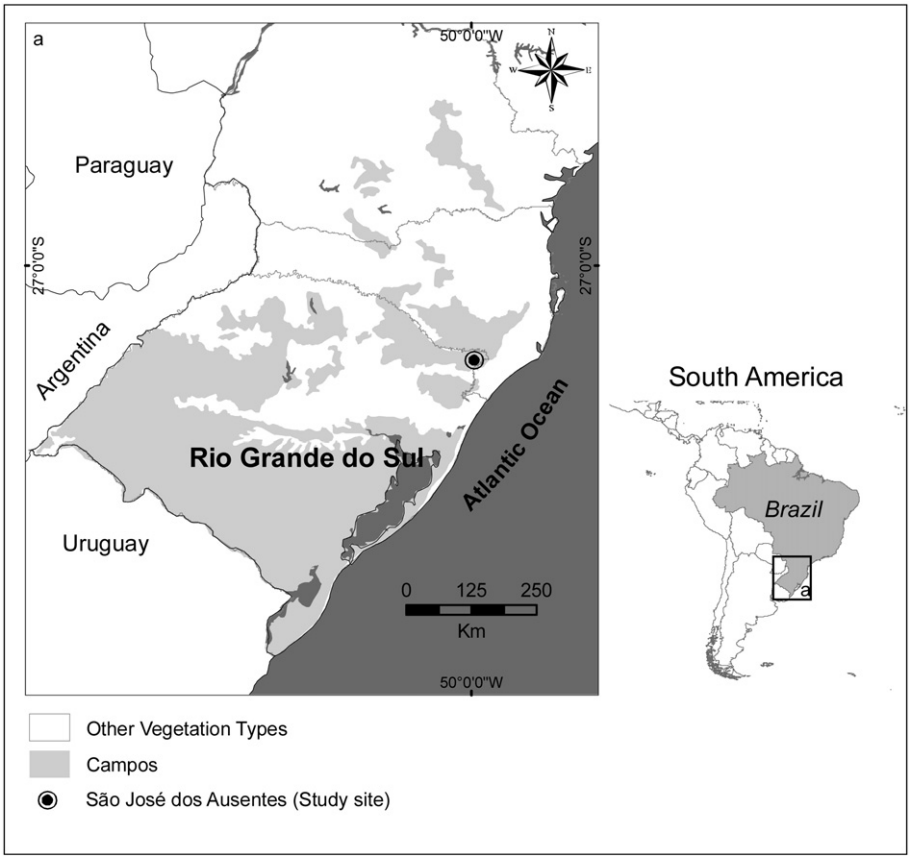

Fig. 1. Map showing the Campos on the southern Brazil and the locality of the study area on the highlands of Rio Grande do Sul state.