ARTICLE IN PRESS

Journal of Archaeological Science: Reports xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

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

Dynamics of fire, precipitation, vegetation and NDVI in dry forest environments in NW Argentina. Contributions to environmental archaeology

L. Susana Burry[a], Patricia I. Palacio[b], Mariano Somoza[a], Matilde E. Trivi de Mandri[a], Henrik B. Lindskoug[c], M. Bernarda Marconetto[c,*], Héctor L. D'Antoni[d]

[a] Laboratorio de Palinología y Bioantropología, Departamento de Biología, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Argentina
[b] CONICET, Laboratorio de Palinología y Bioantropología, Departamento de Biología, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Argentina
[c] Instituto de Antropología de Córdoba, CONICET, Facultad de Filosofía y Humanidades, Universidad Nacional de Córdoba, Av. Hipólito Yrigoyen 174, CP 5000, Córdoba Capital, Argentina
[d] NASA Ames Research Center, Moffet Field, CA, USA

ARTICLE INFO

Keywords:
Fire
Precipitation
NVDI
Hindcasting model
Environmental archaeology
Remote sensing
Northwestern Argentina

ABSTRACT

Fire has shaped the environment and has been important for human cultural development. In this paper, we propose to study past fire events using ecological modelling. For instance, the ecology of fire can help us to understand and interpret archaeological problems related to past settlement patterns or environmental scenarios. Variation in fire regimens are related to both, vegetation and precipitation fluctuations. Recently, we have model past ecosystem dynamics using remote sensing in the Ambato Valley (Catamarca NW Argentina) ranging from 442 to 1998 CE. Our aim here is to use remotely sensed vegetation data to enhance our understanding of environmental disturbance in the period 2000–2011. We characterised the spatial-time dynamics of the annual NDVI as an indicator of vegetation functioning. Then we related the NDVI dynamics to precipitation and fire events in an arid highland environment in the area. Further, we analysed the vegetation data (monthly NDVI, MODIS/TERRA satellite, 1km^2 pixels), and the climate data: annual precipitation. Then we calculated the NDVI annual average of every pixel and the NDVI anomalies of every year over the studied period. Lastly, we related NDVI data with annual precipitation and compared the NDVIs prior to and after known fire events in this period. On a spatial scale, the results show that the NDVI values were (a) low in shrublands and in cultivated areas, (b) medium in grasslands and piedmont forest with anthropic impact, and (c) high in highland forests. Within the studied time-period, extreme positive and negative anomalies were detected. The precipitation inter-annual variations were greater than the NDVI inter-annual variations, thus demonstrating that in some areas of the valley the horizontal precipitation can make important contributions to the ecosystem humidity. Extreme negative anomalies were observed the year of fire and fire scars at least for the next two years. These results demonstrate the relation between structure and function of vegetation, precipitation and fire. Understanding these relations can enable us to explain results when hindcasting ("predicting" what happened during past episodes of climate change) palaeoenvironmental conditions and fire events, thus helping us to interpret different archaeological contexts related to fire events.

1. Introduction

During the last couple of years, we have worked with palaeoenvironmental reconstructions in the Ambato Valley, Catamarca Province, northwestern Argentina (Lindskoug, 2010; Lindskoug, 2014; Lindskoug, 2016a; Lindskoug and Marconetto, 2014; Marconetto, 2008; Marconetto, 2009; Marconetto, 2010; Marconetto and Lindskoug, 2015; Marconetto et al., 2014; Marconetto et al., 2015). At the same time, an ethnographical work about the perception of climate and ethnometeorology was published (Bussi, 2015). We initiated these studies because of the necessity to understand the environmental context of past populations in the inhabited area. Archaeological evidence shows that the earliest occupations of the area took place during the Formative Period at the beginning of the first millennium. Settlement data seems

* Corresponding author.
E-mail address: bernarda.marconetto@gmail.com (M.B. Marconetto).

http://dx.doi.org/10.1016/j.jasrep.2017.05.019
Received 25 October 2016; Received in revised form 20 April 2017; Accepted 15 May 2017
2352-409X/ © 2017 Elsevier Ltd. All rights reserved.

to indicate that the area had been continuously occupied until around 900–1000 according to AMS dating (Marconetto et al., 2014), which corresponds to the Regional Integration Period and the last phase of Aguada occupation in the area. Several of the archaeological sites in the area, Iglesia de Los Indios, Martínez 2 and Piedras Blancas, associated to the Aguada Culture, indicated a rapid abandonment as a result of fire events (Gastaldi, 2010; Laguens, 2006; Lindskoug, 2016a; Lindskoug, 2016b; Marconetto and Gordillo, 2008). The first palaeoenvironmental studies had indicated a possible drought at the end of the occupation of the area by the Aguada culture at the end of the first millennium (Marconetto, 2009; Marconetto, 2010). These evidence led us to initiate studies about past fire regimes in the area (Lindskoug, 2010; Lindskoug, 2014; Lindskoug, 2016a; Lindskoug, 2016b; Lindskoug and Marconetto, 2014), to analyse whether the abandonment of the valley in the last phase of the Aguada occupation was related to forest fires. Further, we also applied a method to analyse the past vegetation based on an ecosystem-process model (D'Antoni, 2006; Marconetto et al., 2015) called Hindcasting Ecosystems Model (HEMO). This model uses Normalised Difference Vegetation Indexes (NDVI) to make retrodictions about past vegetation patterns in the Late Holocene. The HEMO is a model that employs non-linear methods, like the Artificial Neural Network, built from a training model with modern NDVI and growth ring data or some other annual resolution proxy. The NDVI is calculated from spectroscopic satellite data. Satellites orbiting the earth get periodical data, available at open databases such as NOAA, NASA, thus obtaining time series. The NDVI is related to the vegetation cover and productivity, and indirectly, to precipitation, temperature, drainage, mineralogical composition and soil biota, and to all those factors that determine the vegetation status. Time series from NDVI data allow supervising the ecosystem dynamics. Then, from the training model, the retrodiction of old-time NDVI (paleo-NDVI) at an annual resolution is done, employing the training model and the growth rings belonging to the period to be retrodicted.

Thus, the HEMO permits the estimation of the vegetation status and the variations suffered in the past. Those changes can be compared with other contemporaneous environmental factors. The HEMO has already retrodicted the paleo-NDVI of the Ambato having obtained the first results for the period 442–1998 CE. It also detected great intensity paleo-NDVI fluctuation periods in the V and XV centuries. Furthermore, the model proved to be sensitive to global-scale phenomena, such as the Little Ice Age and the Medieval Warm Period Valley (Burry et al., 2017; Marconetto et al., 2015).

In this paper, we aim to characterise the spatial distribution and the annual dynamics of the NDVI (period 2000–2011) in a highland forest environment northwest of Argentina and to relate the NDVI dynamics with precipitation and fire events to see possible patterns, which can help to understand the ecology of fire in the area. The knowledge of the modern ecosystem dynamics will let improve our description of the vegetation-precipitation-fire relationship of the area, which will eventually lead to the posing of more precise palaeoenvironmental inferences.

The application of this in the field of environmental archaeology can help us to understand the palaeoenvironmental context of the past Aguada society in the area and can be used in other areas with similar environmental conditions to analyse past societies from different angles.

1.1. Ecosystems

Understanding of the environmental disturbance impact over a region requires of a characterisation of the vegetation state. Ecosystems can be characterised either by their structural or by functional parameters. The characterisation of an ecosystem by their structural parameters alone shows some deficiencies, for example the inertia of the vegetation structure can defer the perception of the ecosystem response to a disturbance (Milchunas and Lauenroth, 1995) or to changes related to climatic variations; not only that, but also the ecosystem functioning usually has a more rapid response in time than it does in structure. Therefore, the use of functional attributes represents a clear advantage to the characterisation of ecosystems into bio zones (Paruelo et al., 1998). An additional benefit is that functional attributes can be monitored through satellite data (Malingreau, 1986) which apart from exploring the vegetation dynamics, help describe the spatial heterogeneity of ecosystems. Moreover, D'Antoni and Spanner (1993) used satellite images to build models for paleoecology. Time series of continuous earth surface observations based on vegetation estimates have also significantly improved the comprehension of plant variation from a regional to a global scale (Fensholt et al., 2009; Schucknecht et al., 2013). They allow monitoring the ecosystem dynamics.

1.2. NDVI

The Normalised Difference Vegetation Index (NDVI) is related to plant cover and the vigour and productivity of vegetation while time series permit the monitoring of the ecosystem dynamics. Time and space variations of the plant photosynthetic activity have close relation with the soil water availability, especially in arid to sub-humid ecosystems (Fabricante et al., 2009; Iglesias et al., 2010; Ji and Peters, 2003; Justice et al., 1985; Nicholson et al., 1990; Tucker et al., 1985). However, the warmer temperatures of the growing season increase the plant productivity in cold environments (Srur et al., 2011). In this sense, NDVI time series have been compared to climatic variable time series, with the aim of exploring correspondences between geophysical elements and variations of the green index (Herrmann et al., 2005; Hickler et al., 2005; Xiao and Moody, 2005).

1.3. Precipitation

Diverse authors have found a connection between the mean annual precipitation and the spatial variations of NDVI on a regional level (Lauenroth, 1979; Le Houérou, 1984; McNaughton, 1985); however, time patterns could be explained not only by precipitation but also by a set of factors (Jobbágy et al., 2002; Lauenroth and Sala, 1992; Le Houérou et al., 1988). Therefore, the NDVI time dynamic behave in a complex manner seemingly either because of the vegetation memory or because of the inertia with regard to previous precipitation periods (Nicholson et al., 1990; Oesterheld et al., 2001; Ogle and Reynolds, 2004; Wiegand et al., 2004).

1.4. Fire

Moreover, fire is also a factor that controls the vegetation dynamics and it frequently affects forest-shrubby/herbaceous ecotonal areas (Bond and van Wilgen, 1996). In addition, fire affects the increasing or decreasing woody biomass within a landscape (Murphy et al., 2014). Fire regimes are influenced by both climatic factors controlling the fuel production and human activity (Bond and van Wilgen, 1996; Grau and Veblen, 2000). The vegetation vigour and the hydric state of fuels can determine the ignition probability, conditioning to some extent the propagation of fire (Burgan et al., 1998). In mesic forests, fire is more frequent during continuous dry periods that can last from less than a year to many decades. In contrast, in relatively dry forests, fire can be limited by shortage of fine fuel. Moreover, fire occurrence often increases a year or a few years after above-average moisture availability (Grau and Veblen, 2000). By allowing the monitoring of vegetation conditions at a regional scale, the NDVI data can detect fire events that have already occurred and provides an insight into the potential risks of fire (Zipoli et al., 2000).

1.5. Archaeology and fire

Evidence of fire in the archaeological and geological records can

Download English Version:

https://daneshyari.com/en/article/7444399

Download Persian Version:

https://daneshyari.com/article/7444399

Daneshyari.com