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Phytolith analysis reveals the intensity of past land use change in the Western Ghats biodiversity hotspot

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ABSTRACT

This paper presents a study of phytoliths (opal silica bodies from plants) from sediment sequences obtained from two tropical forest patches in the Western Ghats of India: a sacred grove (sequence covers last 550 cal BP) and a forest patch in a plantation (sequence covers last 7500 cal BP). The sites are located at mid-elevation (c. 650–1400 m above sea level) in a mosaic landscape showing anthropogenic open habitats and plantation as well as some evergreen forests. The aim of this paper is to evaluate the landscape composition of grassland and forest over time in the region, grassland being invariably shaped by anthropogenic activities, particularly fire for cultivation. In particular, we compare the phytolith record with the previously published pollen record from the same cores in order to improve our understanding of grass diversity and abundance over time. We identified and classified phytoliths into 34 morphotypes from five taxonomic groups: Poaceae (grasses), Cyperaceae (sedges), Arecaceae (palms), Pteridopsida (ferns) and woody dicotyledons (broad-leaved trees and shrubs). We also calculated the humidity–aridity index (Iph). First, our results show that grasses are the most represented phytolith types in both sites, followed by broad-leaved trees and shrubs, palms, sedges, and ferns. Second, the highly variable climatic index Iph over the last 1000 years suggest that changes in phytolith percentage (e.g. broad-leaved trees) might be caused by human agro-pastoral activities, such as clearing through fires and irrigation. Prior to these human activities, the phytolith signal for early Holocene climate is congruent with the existing literature. Finally, this study compares new phytolith results with previous pollen data from the same sites. We find good agreement between these two botanical proxies throughout, thus validating our findings. We provide important evidence regarding the history of environmental change due to anthropogenic activities in the Western Ghats. This has important implications because it provides insights into how tropical forest will respond to increased intensity of human activities.

1. Introduction

Recent palaeoecological studies in the Western Ghats of India have analysed fossil pollen grains and charcoal time-series to shown the importance of grassland-forest dynamics in a human modified landscape (Bhagwat et al., 2012, 2014). However, it is desirable to consolidate these findings with an independent line of evidence and with an improved taxonomic identity of grasses (Poaceae) and broad-leaved trees to better understand the dynamics of the whole system.

The origin of mid-elevation (c. 650–1400 m a.s.l) grasslands vegetation mosaics remains controversial because the date of initial forest removal for agricultural proposes is unattested. It is believed to be around 6000 and 3500 cal BP (Caratini et al., 1994) but earlier agricultural activities might have existed in the region throughout

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the Holocene (Caratini et al., 1994; Chandran, 1997). It remains difficult to ascertain using pollen studies alone (e.g. Bhagwat et al., 2012, 2014) whether the grassland-forest dynamics are solely induced by human activities. . Therefore, using phytolith as a proxy here we consolidate the understanding of landscape dynamics in the mid-elevation forest-grassland mosaics of the Western Ghats of India.

Except for a few cultivated grass species corresponding with cereal grains, the identification of grasses in temporal sediment sequences has always been a challenge in palaeoecology due to the limitations in identifying fossil pollen grains at sub-family level (Fearn, 1998). However, grasses are excellent environmental indicators (Ghosh et al., 2011) and they also give information on dominant photosynthesis pathways (C3 or C4 grasses) that can be directly interpreted in terms of environmental and climatic conditions (Gu et al., 2008; Edwards et al., 2010; Strömberg, 2011). Phytoliths form a useful proxy because it can be useful to provide additional information about changes in grass diversity over time that pollen gains alone do not. This information can provide further insights into whether the presence of grassland in landscape mosaics is due to human activities, environmental causes or purely climatic factors.

Phytoliths, the opaline silica bodies precipitated in or between cells of plant tissues, provide robust information about identification of grasses often to subfamily level (Piperno, 2006). For example, phytoliths have been successfully applied in palaeoeoeclogy and archaeology to understand the consequences of slash-and-burn agricultures on vegetation (Piperno, 1989), to reconstruct humidity, temperature, and aridity (e.g Bremond et al., 2005, 2008), and to understanding diet and past plant uses (e.g Harvey and Fuller, 2005; Saul et al., 2013). Moreover, one of the main advantages of using phytoliths in multiproxy studies lies in their size, rate of transport, and resistance to fire and changes in pH (e.g. Harvey and Fuller, 2005; Aleman et al., 2014; Cabanes and Shahack-Gross, 2015). This is particular useful when studying disturbed ecosystems such as the human-dominated landscape of the Western Ghats (Ranganathan et al., 2008).

The aim of this paper is to improve our understanding of the landscape composition of grassland and forest over time at mid-elevation evergreen forests in the Western Ghats of India using the analysis of phytolith assemblages. The key question we are interested in answering is: what impact does the increased intensity of human activities have on the Western Ghats landscape?

Our objectives are:

- Analyse the phytolith record for two cores from mid-elevation forest patches in the Western Ghats region.
- Compare this phytolith record with previously published pollen record from the same cores in order to improve our understanding of grass diversity and abundance over time.
- Discuss the nature and magnitude of anthropogenic and climatic vegetation changes on the basis of the phytolith and pollen record at local scale and regional scale.

An accurate knowledge of forest-grassland dynamics in the region will improve our understanding of human activities in the past, which has important implications because it provides insights into how the tropical forest will respond to increased intensity of human activities in the future.

2. Regional setting

The Western Ghats of India was amongst ten regions in the world to be first identified as tropical forest 'hotspots' by Norman Myers in 1988 (Myers et al., 2000) and is now considered a hotspot of biodiversity. The study site was located in the southwestern part of Kodagu district, Karnataka state in Southern India. The landscape in the study sites is comprised of paddy cultivation in low-lying valleys, agroforestry systems on hill slopes, and tropical forest patches. Among the forest patches, some are considered sacred groves, which are an example of community-based conservation. In this phytolith study we extracted two sedimentary cores from small wet forest hollow on the forest patch at the Bopaiah plantation (BOP, 12° 9′ 14″N, 75° 42′ 47.002″E) and on the Mythadi sacred grove site (MY, 12° 13′ 13″ N, 75° 47′ 31″ E), at 910 and 879 m a.s.l, respectively. BOP was a 172 cm sedimentary core extracted from a relatively flat foothill forest patch in a coffee (*Coffea arabica var. robusta*) and betelnut palm (*Areca catechu*) plantation. The MY sedimentary core was 44 cm in length and extracted from a sacred grove within the same region (Fig. 1).

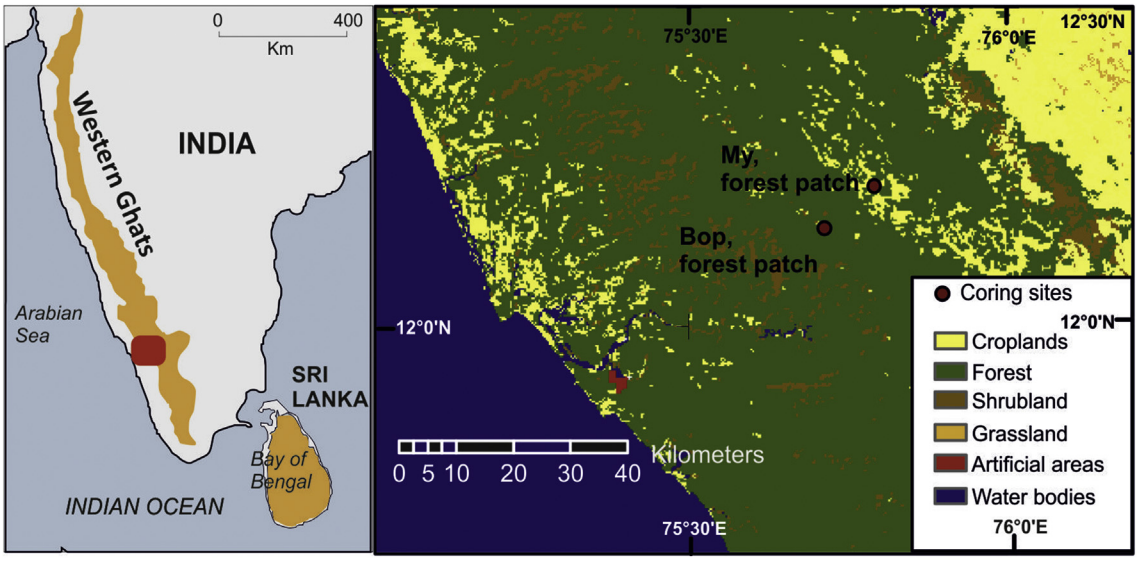

Fig. 1. Map of India showing the distribution of the Western Ghats and the location of the two study sites. Map from figure b is from GlobCover (http://due.esrin.esa.int/page_globcover.php) and it illustrated land cover types and the location of the two study sites.

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