Volume VI ● Issue 2/2015 ● Pages 151–160

INTERDISCIPLINARIA ARCHAEOLOGICA
NATURAL SCIENCES IN ARCHAEOLOGY

homepage: http://www.iansa.eu

Humans and Water in Desert "Refugium" Areas: Palynological Evidence of Climate Oscillations and Cultural Developments in Early and Mid-Holocene Saharan Edges

Anna Maria Mercuri[a], Assunta Florenzano[a*], Carlo Giraudi[b], Elena A. A. Garcea[c]

[a] *Laboratorio di Palinologia e Paleobotanica, Dipartimento di Scienze della Vita, Università di Modena e Reggio Emilia, viale Caduti in Guerra 127, 41121 Modena, MO, Italy*
[b] *ENEA C. R. Saluggia, Strada per Crescentino 41, 13040 Saluggia, VC, Italy*
[c] *Dipartimento di Lettere e Filosofia, Università di Cassino e del Lazio Meridionale, via Zamosch 43, 03043 Cassino, FR, Italy*

ARTICLE INFO

Article history:
Received: 30th April 2015
Accepted: 21st December 2015

Key words:
palaeoecology
pollen
wet habitats
archaeology
climate change
Libya
Niger

ABSTRACT

Saharan anthropic deposits from archaeological sites, located along wadis or close to lakes, and sedimentary sequences from permanent and dried basins demonstrate that water has always been an attractive environmental feature, especially during periods of drought. This paper reports on two very different examples of Holocene sites where "humans and water" coexisted during dry periods, as observed by stratigraphic, archaeological and palynological evidence. Independent research was carried out on the Jefara Plain (Libya, 32°N) and the Gobero area (Niger, 17°N), at the extreme northern and southern limits of the Sahara, respectively.

The histories of the Jefara and Gobero areas, as revealed by the archaeological and palaeoenvironmental reconstructions, suggest that these areas were likely to have been visited and exploited for a long time, acting as anthropic refugia, and therefore they have been profoundly transformed. Human presence and actions have conditioned the local growing of plants and selected a more or less synanthropic flora. Today, modern conservation strategies should take into consideration that water reservoirs, which are crucial for the long-term conservation of biodiversity, have provided refugia in the past just as they presently do under global warming conditions.

1. Introduction

The concept of a *refugium* is frequently combined with that of mountains in desert ecosystems (Quézel 1997; Anthelme *et al.* 2008; Migliore *et al.* 2013). *Evolutionary* and *ecological* refuges have different chronological and spatial scales (Quézel, Martinez 1960; Maley 1981, 2010; Bennet, Provan 2008; Watrin *et al.* 2009; Davis *et al.* 2013), but both may be recognised in the history of currently hyper-arid regions. Although there are different approaches to this matter, in general, refugia are regarded as places where the local microclimate was different from the regional climate, and therefore organisms may have retreated, *persisted in* or *expanded from*, under changing environmental conditions (according to the habitat-based definition of refugia by Keppel *et al.* 2012). Under dry or cold climate oscillations, for example, organisms have a higher chance of survival in these places.

With regard to deserts, including current ethnographic evidence (Mandaville 2011; di Lernia *et al.* 2012), it is especially evident that, little by little, water has triggered the movements of plants, animals and humans. Across the history of desert regions, organisms have followed water, and when climate conditions became drier and water basins and rivers reduced their distribution or flow, then humans have reached the same refuges where water and plants have already concentrated (Kuper, Kröpelin 2006; Mercuri 2008a; Florenzano *et al.* 2016).

This leaves open the question as to whether the plant cover near places of water (or wetlands) is natural or anthropogenic.

Saharan anthropic deposits from archaeological sites, located along wadis or close to lakes, and sedimentary sequences from permanent and dried basins, have demonstrated that water has been an attractive environmental feature especially during periods of drought (*e.g.*, Smith *et al.* 2005; Garcea 2013a).

*Corresponding author. E-mail: assunta.florenzano@unimore.it

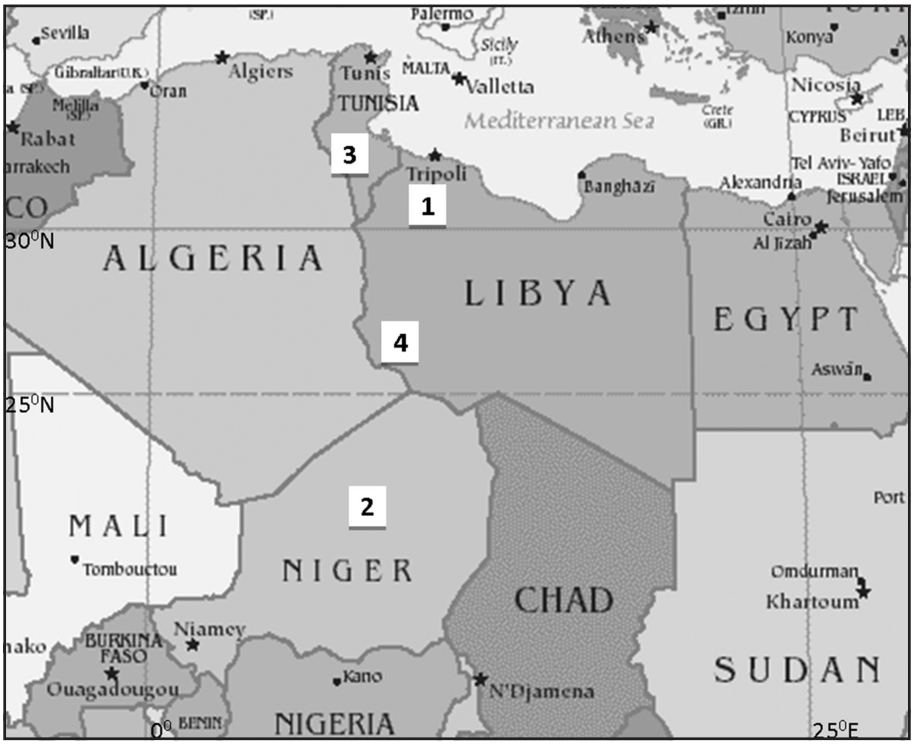

Figure 1. Location map of the sites discussed in the text: 1 – Jefara Plain; 2 – Gobero area; 3 – Chott Rharsa basin; 4 – Tadrart Acacus Mountains.

This paper reports on two, very different, examples of evidence concerning "humans and water" as observed in the stratigraphic, archaeological and palynological studies carried out on Holocene deposits at the extreme limits of northern and southern Sahara.

2. The case studies

The two case studies reported in this paper come from the Jefara Plain (Libya, 32°N) to the north and the Gobero region (Niger, 17°N) to the south of the present Sahara desert (Figure 1). They currently lie at the margins of the widest desert of the world, both regions that are known to receive more rainfall and have greater vegetation cover than the central regions. Central Sahara lies between 18º and 30º N, its annual rainfall is below 25 mm, and its underground aquifers sometimes penetrate through to the surface resulting in oases (White 1983).

The areas of the Jefara and Gobero have been studied using an interdisciplinary approach that involved environmental investigations in the general archaeological research. Palaeoenvironmental reconstructions resulted from an integration of archaeological, geological, sedimentological and palynological studies in the two areas. In fact, they are both multipoint sites characterised by a complex set of sedimentary and cultural contexts (Giraudi 1995; 2005; Barich *et al.* 2006; Garcea, Giraudi 2006; Sereno *et al.* 2008; Barich 2013; Garcea 2013a).

Pollen analyses resulted in a very laborious and time-consuming procedure. Many sandy and organic-poor types of sediment were treated for pollen extraction through sieving and floating procedures (van der Kaars *et al.* 2001; Florenzano *et al.* 2012). Although several grams of sediment were processed, quite a lot of samples were sterile and others showed very low pollen concentration (expressed as pollen grains per gram = p/g). Nevertheless, pollen in a good state of preservation was found in several samples. The high interest of these contexts, commonly associated with archaeological deposits and radiocarbon dating, encouraged the accomplishment of these pollen analyses and gave the possibility to compare the pollen data with the other results obtained from different analyses.

2.1 Case study 1: the Jefara Plain (Libya; 32°00′ N, 11°41′ E; c. 230 m asl; c. 7800–4600 cal BP)

At the northern fringes of the Sahara desert, Quaternary sedimentary sequences were identified in the Jefara Plain in front of the northern scarp of the Jebel Gharbi, a mountain range in northwestern Libya. These sequences were mostly formed of dark-grey palustrine sediments interbedded with aeolian deposits; these were studied in order to establish the timing of marsh formation and the periods of increased groundwater flow (Giraudi *et al.* 2013). Moreover, a number of Neolithic archaeological features, especially hearths, suggested that human frequentation had occurred on a seasonal basis for those transiting between the Mediterranean coast and the mountain range and the pasture of livestock (Lucarini 2013).

As the geomorphologic and stratigraphic features of the Jebel Gharbi and the Jefara Plain showed that Holocene sediments were rather discontinuous in this area, since they had been subjected to strong wind deflation and erosion by ephemeral streams, two sites about 300 m apart, SJ-06-87 and SJ-06-88, where the aeolian sediments were interbedded with dark palustrine sediments, were selected

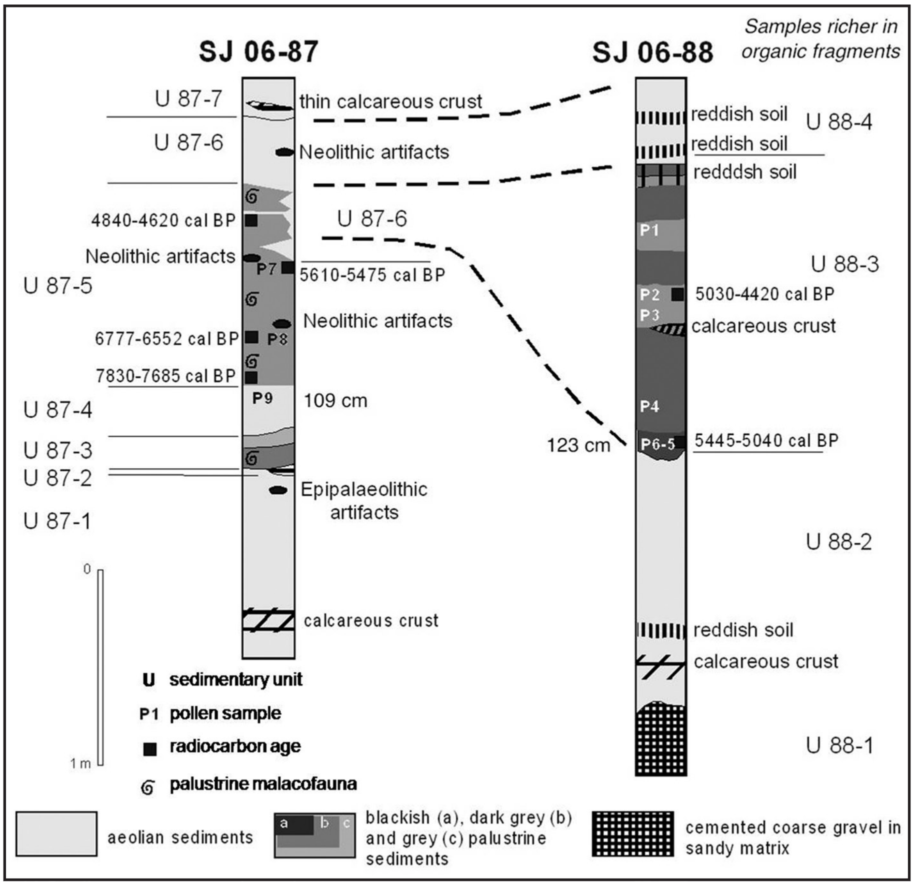

Figure 2. Sedimentary sequence and pollen sampling from the sites SJ-06-87 and SJ-06-88 in the Jefara Plain (from Giraudi *et al.* 2013, modified).

for pollen analyses (Giraudi *et al.* 2013). Six radiocarbon dates made on organic dark sediments demonstrated that these sediments accumulated during a period of about three thousand years. Pollen samples were taken from the same sediments (Figure 2). About 200 pollen grains were counted on average in nine samples. Counts of Non Pollen Palynomorphs (especially algae; van Geel 2001), and microscopical particles of charcoal, helped to complete the palaeoecological information.

The palynofacies from the two sites looked different. The mean pollen concentration was very low (800 p/g in SJ 06-88, and <100 p/g in SJ 06-87) but a high number of taxa (more than 100 taxa, from 14 to 47 per sample) was observed. The pollen diagram shows a dominance of pollen from herb plants (Figure 3). Trees were insignificant with a mean percentage sum of 6%, and prevalence of *Tamarix* and *Ficus,* followed by *Salvadora persica* and *Capparis*. Pollen of anemophilous trees included the deciduous *Quercus* and *Betula*, and conifers, such as *Pinus* and *Cedrus*, that derived from long-distance transport from the Mediterranean area. These types of records may be interpreted as indicators of wind fluxes that, generally, are more intense during dry climate phases (Lézine *et al.* 2011; Mercuri 2015). In these spectra, Poaceae and Cyperaceae were ubiquitous together with different taxa of Chenopodiaceae, Asteraceae and *Plantago*. Altogether, the prevalent vegetation of the Jefara

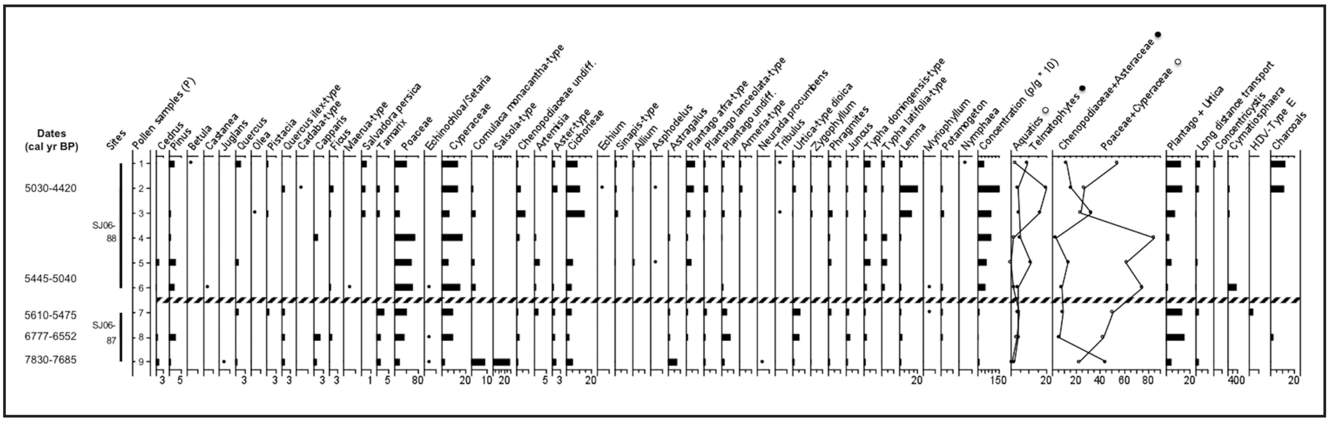

Figure 3. Pollen diagram of the samples from the Jefara Plain.

Plain was a shrub forest of alluvial plains or a wadi vegetation (with *Ficus*, *Capparis*, *Salvadora persica* and *Tamarix*) with extended grassland and a water pool where the water level probably changed seasonally.

Among the high biodiversity of herbs, the most interesting evidence is the high values of *Plantago* (*P. afra*-type, *P. lanceolata*-type, *P.* undiff.) and *Urtica*-type *dioica*, together with charcoal particles > 200 µm. Large microcharcoals are evidence of local fires, and might have been produced by fireplaces (Clark 1988; Sadori *et al.* 2015). *Plantago* species grow on trampled layers, while *Urtica* species include nitrophilous plants. Plantains also grow well in sandy soils, where trampling causes compaction and a reduction of soil water porosity, and moisture content is higher in the upper layers of the soils due to capillarity (Noë, Blom 1981). Significant values of *Plantago* pollen are evidence of trampling in the relevant depositional phases (Behre 1981). An increase of humans or animals enriched the soils with organic matter, favouring also the local growth of nettles. Therefore, pollen grains of *Plantago* and *Urtica*-type *dioica* are usually linked to the spread of human landscapes during the late Mid-Holocene in regions facing the Mediterranean basin (Mercuri *et al.* 2012). In the Jefara, the archaeological evidence is not always clear, but the combination of pollen and microscopic charcoal was interpreted as evidence of "trampling, organic enrichment and fires". This relative increase of human frequentation at the sites is evident in the layers dated to around 6.7 and 5.0 ka BP, and especially in the last part of this period (P1 and P2 in Figure 3). This probably depended, partly or principally, on the local availability of water.

Besides pollen from plants of wet environments, algal remains are the most unambiguous record from water places. *Cymatiosphaera* is related to brackish water with high nutrient content, and may live in the surface sediments of intertidal marshes (Medeanic 2006; Mudie *et al.* 2010). Also, the rare records of *Pseudoschizaea circula*, together with other Zignemataceae spores, indicate brackish water or fresh water. These algae are an index of fresh and/or brackish water at the sites, signalling the local presence of a low water level during phases of the Mid-Holocene.

In the wider Saharan region, a desiccation of the eastern Sahara is known to have occurred at around 6.3–6.2 ka BP, while in central Sahara the beginning of a shift towards more permanent aridity has been registered from approximately 6.0 ka BP onwards (Mercuri *et al.* 2011; Cremaschi *et al.* 2014), and the spread of psammophilous vegetation marking current hyperarid habitats occurred at around 5.4 ka BP. In the Sahara, in general, two major Holocene wet periods are known from palaeoenvironmental records: the first dated between about 10.5 ka BP and 8.5 ka BP, and the second dated between about 7.5 and 4.5 ka BP (Cremaschi *et al.* 2010). The wet phases found in its sedimentary sequences correlate with the phases of expansion of the Saharan lakes (Figure 4). Water table levels increased at 7.5–5.8 ka BP, and at around 5.5–5.0 ka BP (Chott Rharsa basin, Tunisia; Swezey *et al.* 1999). The pollen diagram from the Jefara shows a dry phase at the bottom (high Chenopodiaceae+Asteraceae), and then the expansion of grasslands (high Poaceae+Cyperaceae; Figure 3). As mentioned above, the local availability of water is evident because a rich biodiversity of hygrophilous plants, aquatics and algal remains was observed in the samples dated at around 6.7 and 5.0 ka BP. High values of aquatics were actually recorded at around 5.5–5.0 ka BP, during a period of local expansion of xerophytes (Figure 3).

Therefore, we can conclude that the permanence of water encouraged humans and animals to move around and live in the area even during expansions of xerophilous vegetation and dry climatic phases.

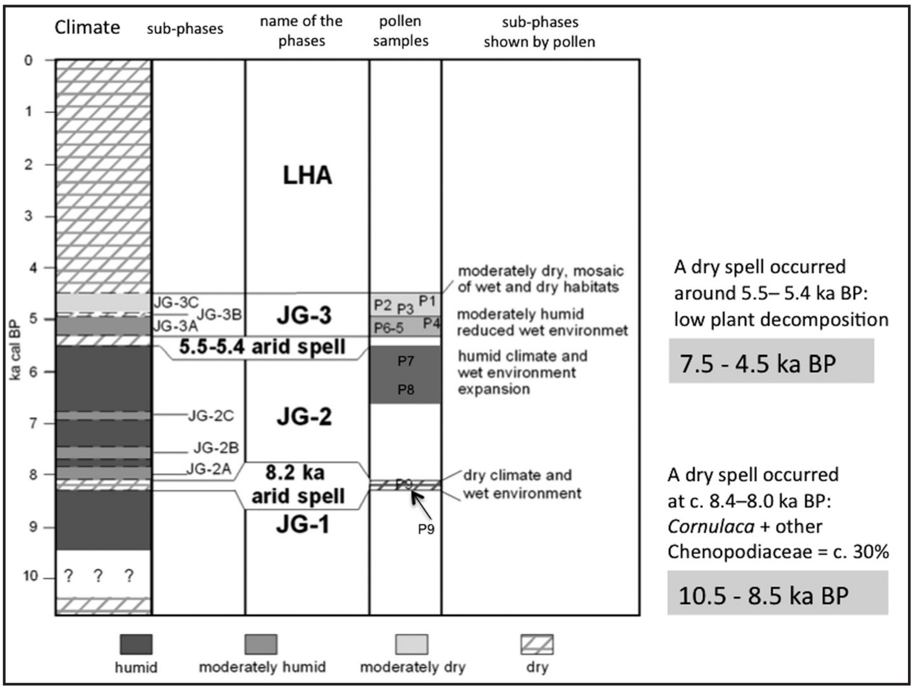

Figure 4. Holocene climatic and environmental phases in the Jefara Plain (modified from Giraudi *et al.* 2013).

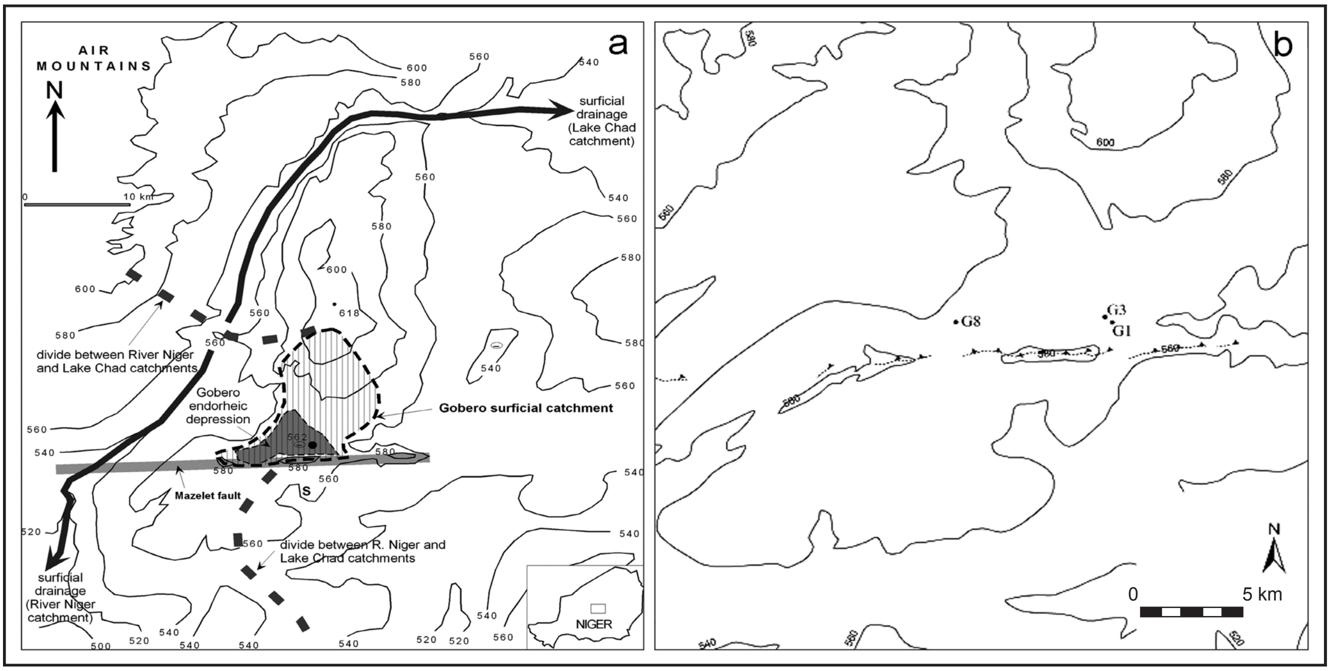

Figure 5. The Gobero area: a – Gobero basin and catchment area; b – Map of the Gobero area with the sites (modified from Garcea 2013a).

2.2 Case study 2: the Gobero Lake (Niger; 16°55′ N, 9°30′E; c. 560 m asl; c. 10,000–3800 cal BP)

During the Holocene humid periods, a lake formed in the Gobero basin and a spillway connected the Gobero area with Lake Chad. During the Early and Mid-Holocene periods, human settlements were established on the shores of the ancient lake and over 200 burial sites within the settlements were found and assigned to the Pre-Pastoral (c. 9.5–8.2 ka BP)

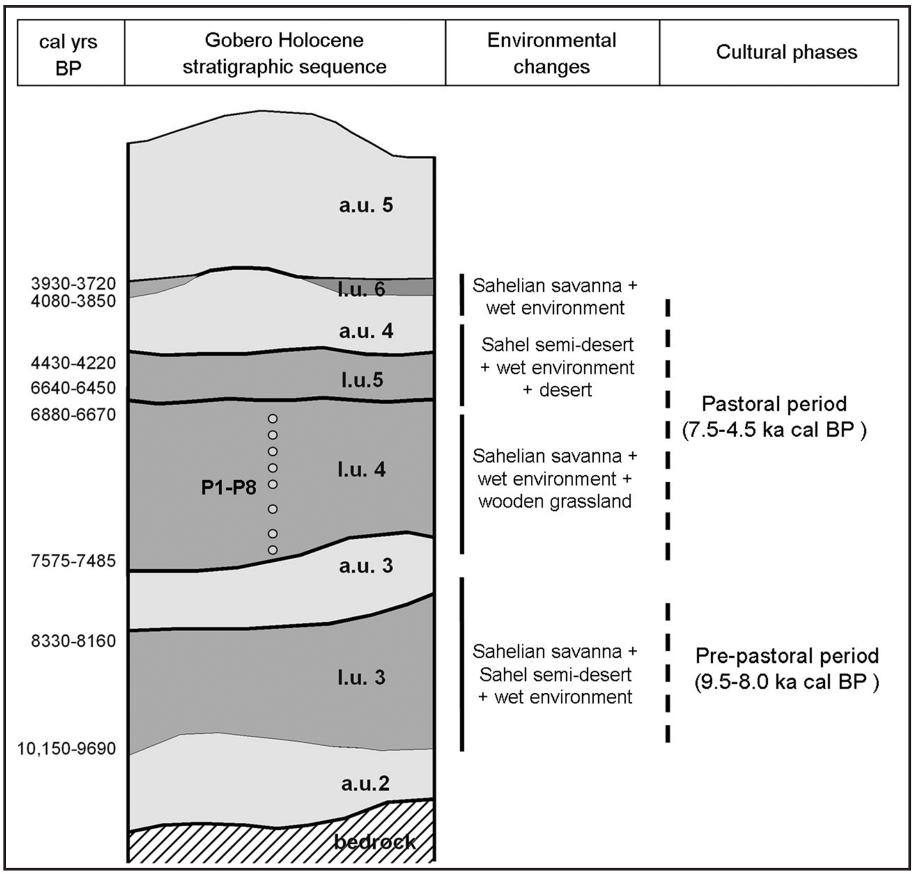

Figure 6. Stratigraphy of the Gobero Lake showing subsequent lacustrine units (l.u.) and aeolian units (a.u.), main vegetation cover, and cultural periods (modified from Giraudi 2013).

and Pastoral (c. 7.1–4.5 ka BP) cultural phases. Besides the archaeological contexts, the chronological framework of the site is based on OSL and radiocarbon dating (Sereno *et al.* 2008).

Pollen analyses were carried out on samples taken from the burial sites (close to the skeletons; G1 and G3) and stratigraphic test excavations in the dried lake (GO1; Figure 5). The pollen record from the lake provided pollen that was less disturbed by human influence than that collected from the burial sites. On the other hand, pollen analyses from the burial sites revealed some human plant uses (Mercuri *et al.* 2013). The combined evidence of pollen spectra from both the burial sites and dried lake allowed us to infer vegetational and environmental changes. Stratigraphic correlations showed that the lake record belongs to the Mid-Holocene phase, dating from about 7575–7485 to 6880–6670 cal BP (Lacustrine Unit 4 in Giraudi 2013; Giraudi, Mercuri 2013, 118). Its stratigraphy was made by subsequent lacustrine and aeolian units corresponding to wet and dry climatic phases, and different cultural phases (Figure 6).

The pollen samples were collected from several lakebeds and burial deposits associated with wet phases. Among the 31 pollen samples taken from eleven lakebeds, pollen spectra could only be obtained from site GO1. A very low pollen concentration, even <100 p/g, and only a few number of pollen taxa (<10 taxa) were found in the samples from the other exposures of lake sediments, showing that selective corrosion had affected the pollen. Thinned exines, probably resulting from hydration / dehydration cycles in the lakes, were usually observed.

Eight pollen samples were taken from the lacustrine unit (l.u. 4 in Figure 6), in about 53 cm of sandy and silty sediments of GO1. About 300 pollen grains per sample were counted on average. Mean pollen concentration was low (440 p/g), but quite a high number of taxa (90, from 14 to 36 per sample) was observed. The pollen diagram shows a dominance of Poaceae and Cyperaceae suggesting the presence of open grassland, and a few shrubs possibly surrounding the margins of the lake (Figure 7). Trees were insignificant with a mean percentage sum of 9%. The hygrophilous tree *Ficus* prevails testifying to a continuous presence of water – at least in the upper surface layer water table. *Capparis* has an isolated peak, and Chenopodiaceae includes the small psammophilous shrub *Cornulaca monacantha*-type. Pollen of anemophilous trees from the Mediterranean basin, especially *Quercus ilex*-type, deciduous *Quercus* and *Pinus*, comes from long-distance transport by wind. In the herb-dominated spectra, Urticaceae (*Laportea*-type) and *Plantago afra*-type are common with Asteraceae and *Zygophyllum*. Herb plants of wet environments, including limno-telmatophytes, such as *Phragmites* and *Typha*, characterise the spectra.

Two main pollen zones, represented here in the diagram (Figure 7), were distinguished:

- at the bottom (zone GO1-a, 53–22 cm, around 7.5 ka BP), pollen concentration is very low; *Ficus* is present together with *Capparis* and *Salvadora*, which grow in wadi communities. Freshwater communities are well-represented especially by *Typha*, growing along the lake shores, while Chenopodiaceae reflect salt and dry environments in the area.
- at the top (zone GO1-b, 21–5 cm, around 6.8 ka BP) there is an increase in pollen concentration, together with pollen of *Typha*, and floating aquatics needing permanent water, such as *Nymphaea* and *Potamogeton*, whereas xerophytes decrease. Algal elements and microscopic charcoal particles were observed in one (20 cm-deep) sample.

These zones reflect two subsequent phases in the life of the lake, a locally drier phase in the bottom part, and seasonal oscillations of water levels. As different plant communities and habitats are represented in the same pollen spectrum, they suggest a mosaic of wet environments, grassland and sandy dunes matching different habitats and seasons around the lake and in the region. Cattails and other plants provided food, woody plants gave fuel, and, in general, plants were collected for multipurpose uses (Mercuri 2008b).

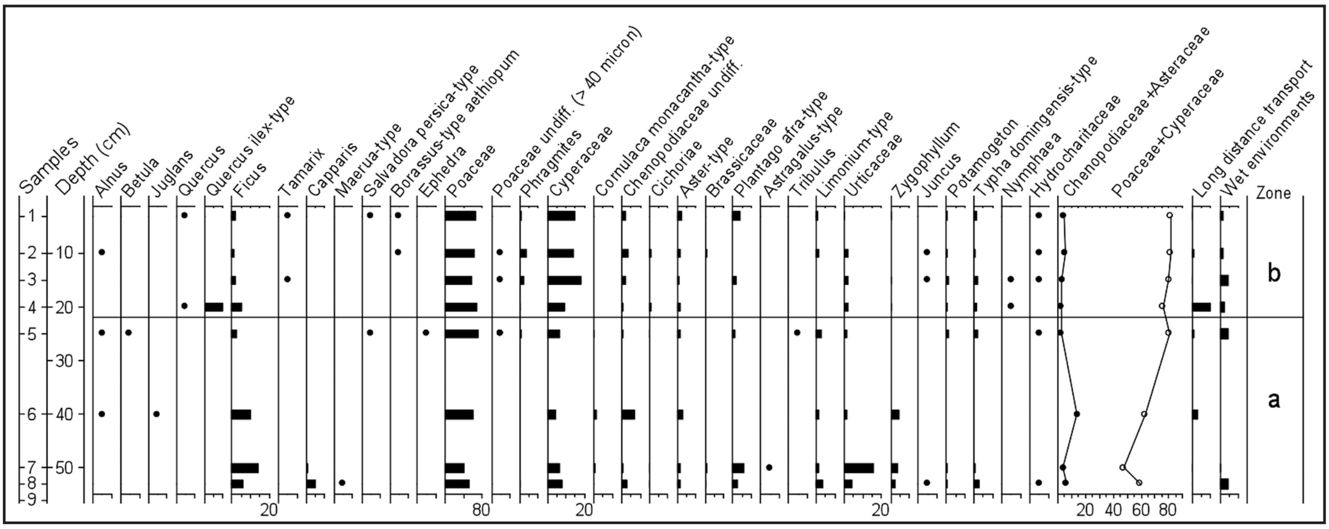

Figure 7. Pollen diagram of GO1 lakebed showing two main pollen zones.

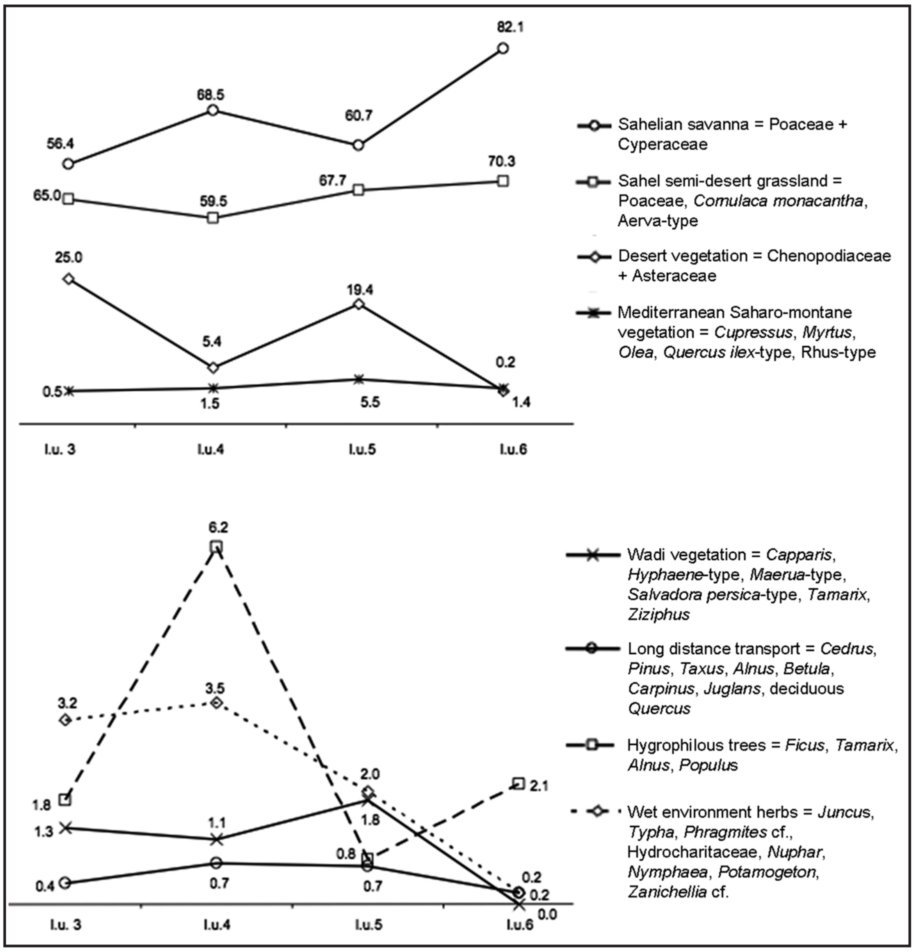

Figure 8. Selected plant associations from pollen analysis of the Gobero area (burial sites and lakebed), and their trends in lacustrine units (l.u.) (modified from Giraudi, Mercuri 2013).

Combined with the record from the burial sites, the pollen from Gobero shows major vegetational changes occurring in the area during the Early and the Middle Holocene (Figure 8). Sedimentological and pollen data suggest that, during the Early Holocene, the environment was more humid and became progressively drier with a climatic warming in the Middle Holocene. At this time, some humid episodes still occurred, but seasonality was enhanced. The landscape was covered by grassland of a Sahelian-type in the rainy seasons, although xerophilous plants spread in the dry seasons. Towards the final phase of human occupation, around 5.0–4.0 ka BP, psammophilous shrubs spread in sandy places with the encroaching of the Sahara, leading to the gradual abandonment of the site. As the local conditions did not seem as dry as in other northwestern African areas, a persistence of significant local wet conditions still occurred at Gobero for a short period of time (around 4.1–3.7 ka BP) within a generally dry climatic phase.

The archaeological reconstruction shows that, during the Pre-Pastoral period, hunter-gatherers settled only in some restricted locations that offered certain crucial resources, such as water bodies (Garcea 2013a; Garcea *et al.* 2013). Once people had begun to choose the richest available patch of land and water body, they were forced into sedentism. In order to cope with decreasing resources, they based their subsistence on the consumption of a wide range of plants that offered a constant available resource. During the Pastoral period, when the climate became more instable, the Gobero palaeolake offered a very favourable and exceptional location for a base camp. In fact, when water supplies are limited, as was the case in southern Sahara, lakes play a determining role in reducing the mobility of herders. Furthermore, when water availability continued to decrease, settling at Gobero was probably not only an efficient logistical choice, but an economic necessity to exploit the resources that were still available on the spot.

3. Discussion

Research in the Saharan and Mediterranean regions has often suggested that cultural developments sometimes show trends that can correspond to climatic changes (Brooks *et al.* 2005; Cremaschi 2002; Kuper, Kröpelin 2006; Mercuri 2008a; Cremaschi, Zerboni 2009; Roberts *et al.* 2011; Maley, Vernet 2013). The main events of profound change in the environmental and cultural systems occurred at around 8.2, 6.0 and 4.2 ka BP (Mercuri *et al.* 2011). During these periods not all the responses were the same, but it is possible that such dry and cool events triggered human adaptation to new environmental conditions. Many palaeoenvironmental archives, for example, have suggested that the Mediterranean natural vegetation was transformed into a cultural landscape in a fairly gradual way (Mercuri 2014). The Saharan environments underwent dramatic changes that considerably affected their ecosystems, and human settlements or their movements, during the Holocene. Archaeological sites are, therefore, reliable archives of both climate and human influences and their impact (Mercuri 2008a; Cremaschi *et al.* 2014).

The interpolation of palaeoenvironmental and archaeological data suggests that around the Gobero Lake there was an ecosystem dynamic similar to that observed around the marshlands of the Jefara Plain. At the northern fringes of the Sahara desert, human frequentation of the Jefara Plain relatively increased at around 6.7–5.4 ka BP. This probably depended on the local availability of water and this encouraged humans and animals to move and live in the area even during drought periods. A similar ecosystem dynamic was observed at the Gobero Lake area (Giraudi *et al.* 2013).

In the central Sahara highlands and mountains (such as, for example, the Tadrart Acacus), although psammophilous vegetation began its expansion after approximately 6.2 ka BP, a change in grassland composition with an increase of more drought-resistant grass species took place at around 5.4 ka BP, and a spread of xerophilous plants followed the increasing aridity in places like the wadi Teshuinat area (Mercuri 2008a). South of it, in the wadi Takarkori area, an almost continuous human occupation of rock shelters occurred since the beginning of the Holocene. The pollen content of the Takarkori rockshelters highlighted a reduction of water availability in the region at c. 8.2 ka BP. However, the persistence of water resources inside the central Saharan massifs allowed a continuous human frequentation, even during the dry period. This confirms that these mountains acted as a refuge for human groups, which in the same period modified their subsistence strategies, including the exploitation of domesticated animals in their subsistence base (Cremaschi *et al.* 2014).

At Gobero, people could benefit from the advantage of living in ecological and social conditions that are typical of edge zones (see Garcea 2013b). These areas are able to offer high biodiversity and social interactions with different groups, providing opportunities to incorporate a wide suite of adaptive responses. In the case of Gobero – sedentism, as a settlement strategy developed by the local pastoralists – probably caused some contrary effects of over-exploitation, which may have become fatal in the long-run. This has been demonstrated, for example, by the pollen research carried out in the Tadrart Acacus. During phases of decrease of water availability all over the desert, over-grazing during the Middle and Late Pastoral cultural phases contributed to accelerating the desertification of such an ecologically-sensitive area (Mercuri 2008a; 2008b).

4. Conclusion

A strong link exists between humans and water – and this is deeply rooted in the biological nature of living organisms and is evident in the general development of human cultures; but in deserts, where "water" is the major limiting factor for life, this is even more stringent. In fact, a small change in water distribution, such as might occur under recurrent climate oscillations, can cause non-negligible changes in both vegetation distribution and cultural adaptations to the environment.

Before the desertification of modern times, both the Gobero Lake and the Jefara marshlands seem to have acted as microrefugia – as they were restricted areas of favourable environmental conditions within regions of largely unfavourable climate; they acted as ecological refuges and were able to provide shelter under the existing highly variable climatic conditions of the Early and Middle Holocene.

The presence of water in these Saharan basins was particularly attractive for humans, and the "sites with water" had, in the past just as it is today, the invaluable role of being nourishing places for living beings, and refugia for plants, animals and humans. Such places offered more favourable conditions for life during critical phases, such as dry oscillations, due, for example, to a decrease in precipitation and a lowering of the water table and small superficial lakes. In this sense they have always acted as biodiversity hotspots that provided the sole source of water for living organisms.

The history of the Jefara, and especially that of Gobero, as revealed by the archaeological and palaeoenvironmental reconstructions, suggests that such sites at the edges of the desert – at its most northern and southern limits – have been visited and exploited for a long time, and therefore have been profoundly transformed, especially when they acted as anthropic refugia. The presence of humans and their action have conditioned the local growing of plants and have selected a more or less synanthropic flora. Modern conservation strategies should take into consideration the fact that water reservoirs, which are crucial for the long-term conservation of the Sahara-Sahel biodiversity today (Vale *et al.* 2015), have provided refugia in the past – as they presently do under global warming conditions.

References

ANTHELME, F., WAZIRI MATO, M., MALEY, J. 2008: Elevation and local refuges ensure persistence of mountain specific vegetation in the Nigerien Sahara. *Journal of Arid Environments* 72, 2232–2242.

BARICH, B. E. 2013: The culture of the oases: late Neolithic herders in Farafra, a matter of identity. In: Bagnall, R. S., Davoli, P., Hope, C. A. (Eds.): *The Oasis Papers 6, Proceedings of the Sixth International Conference of the Dakhleh Oasis Project*. Oxbow Books, London, 39–47.

BARICH, B. E., GARCEA, E. A. A., GIRAUDI, C. 2006: Between the Mediterranean and the Sahara: geoarchaeological reconnaissance in the Jebel Gharbi, Libya. *Antiquity* 80 (309), 567–582.

BEHRE, K.-E. 1981: The interpretation of anthropogenic indicators in pollen diagrams. *Pollen Spores* 23, 225–245.

BENNETT, K.D., PROVAN, J. 2008: What do we mean by "refugia"? *Quaternary Science Reviews* 27, 2449–2455.

BROOKS, N., CHIAPELLO, I., DI LERNIA, S., DRAKE, N., LEGRAND, M., MOULIN, C., PROSPERO, J. 2005: The climate–environment–society nexus in the Sahara from prehistoric times to the present day. *The Journal of North African Studies* 10, 253–292.

CLARK, J.S. 1988: Particle motion and the theory of charcoal analysis: source area, transport, deposition, and sampling. *Quaternary Research* 30, 67–80.

CREMASCHI, M. 2002: Late Pleistocene and Holocene climatic changes in the Central Sahara. The case of study of the south-western Fezzan, Libya. In: Hassan, F. A. (Ed.): *Droughts, Food and Culture*. Kluwer Academic/Plenum Publishers, New York, 65–81.

CREMASCHI, M., ZERBONI, A. 2009: Early to middle Holocene landscape exploitation in a drying environment: Two case studies compared from the central Sahara (SW Fezzan, Libya). *Comptes Rendus Géoscience* 341, 689–702.

CREMASCHI, M., ZERBONI, A., SPÖTL, C., FELLETTI, F. 2010: The calcareous tufa in the Tadrart Acacus Mt. (SW Fezzan, Libya). *Palaeogeography, Palaeoclimatology, Palaeoecology* 287, 81–94.

CREMASCHI, M., ZERBONI, A., MERCURI, A.M., OLMI, L., BIAGETTI, S., DI LERNIA, S., 2014: Takarkori rock shelter (SW Libya): an archive of Holocene climate and environmental changes in the central Sahara. *Quaternary Science Reviews* 101, 36–60.

DAVIS, J., PAVLOVA, A., THOMPSON, R., SUNNUCKS, P. 2013: Evolutionary refugia and ecological refuges: key concepts for conserving Australian arid zone freshwater biodiversity under climate change. *Global Change Biology* 19, 1970–1984.

DI LERNIA, S., MASSAMBA N'SIALA, I., ZERBONI, A. 2012: "Saharan Waterscapes": traditional knowledge and historical depth of water management in the Akakus Mountains (SW Libya). In: Mol, L., Stenberg, T. (Eds.): *Changing Desert: Integrating People and their Environment*. The White Horse Press, Cambridge, 101–128.

FLORENZANO, A., MERCURI, A. M., PEDERZOLI, A., TORRI, P., BOSI, G., OLMI, L., RINALDI, R., BANDINI MAZZANTI, M. 2012: The significance of intestinal parasite remains in pollen samples from Mediaeval pits in the Piazza Garibaldi of Parma, Emilia Romagna, Northern Italy. *Geoarchaeology* 27 (1), 34–47.

FLORENZANO, A., MERCURI, A. M., ALTUNOZ, M., GARCEA, E. A. A., 2016. Palynological evidence of cultural and environmental connections in Sudanese Nubia during the Early and Middle Holocene. *Quaternary International*. DOI 10.1016/j.quatint.2016.01.001.

GARCEA, E. A. A. (Ed.) 2013a: *Gobero: The No-Return Frontier. Archaeology and Landscape at the Saharo-Sahelian Borderland.* Journal of African Archaeology Monograph Series 9. Africa Magna Verlag, Frankfurt.

GARCEA, E. A. A. 2013b: Gobero: the secular and sacred place. In: Garcea, E. A. A. (Ed.): *Gobero: The No-Return Frontier. Archaeology and Landscape at the Saharo-Sahelian Borderland*. Journal of African Archaeology Monograph Series 9. Frankfurt am Main, Africa Magna Verlag, 271–293.

GARCEA, E. A. A., GIRAUDI, C. 2006: Late Quaternary human settlement patterning in the Jebel Gharbi, northwestern Libya. *Journal of Human Evolution* 51 (4), 411–421.

GARCEA, E. A. A., MERCURI, A. M., GIRAUDI, C. 2013: Archaeological and environmental changes between 9500 BP and 4500 BP: a contribution from the Sahara for the understanding of expanding droughts in the "Great Mediterranean". *Annali di Botanica (Roma)* 3, 115–120.

GIRAUDI, C. 1995: Geomorphology and sedimentology in the Ghan and Zargha Wadis and on the Jado Plateau. *Libya Antiqua new series* 1, 18–26.

GIRAUDI, C. 2005: Eolian sand in peridesert northwestern Libya and implications for Late Pleistocene and Holocene Sahara expansions. *Palaeogeography, Palaeoclimatology, Palaeoecology* 218, 161–173.

GIRAUDI, C. 2013: Late Upper Pleistocene and Holocene Stratigraphy of the Palaeolakes in the Gobero Basin. In: Garcea, E. A. A (Ed.): *Gobero: The No-Return Frontier. Archaeology and Landscape at the Saharo-Sahelian Borderland*. Journal of African Archaeology Monograph Series 9. Africa Magna Verlag, Frankfurt, 67–80.

GIRAUDI, C., MERCURI, A. M. 2013: Early to Middle Holocene Environmental Variations in the Gobero Basin. In: Garcea, E. A. A (Ed.): *Gobero: The No-Return Frontier. Archaeology and Landscape at the Saharo-Sahelian Borderland*. Journal of African Archaeology Monograph Series 9. Africa Magna Verlag, Frankfurt, 114–126.

GIRAUDI, C., MERCURI, A. M., ESU, D. 2013: Holocene palaeoclimate in the northern Sahara margin (Jefara Plain, northwestern Libya). *The Holocene* 23, 339–352.

KEPPEL, G., VAN NIEL, K. P., WARDELL-JOHNSON, G. W., YATES, C., BYRNE, M., MUCINA, L., SCHUT, A. G. T., HOPPER, S.D., FRANKLIN, S. E. 2012: Refugia: identifying and understanding safe havens for biodiversity under climate change. *Global Ecology and Biogeography* 21, 393–404.

KUPER, R., KRÖPELIN, S. 2006: Climate-Controlled Holocene Occupation in the Sahara: Motor of Africa's Evolution. *Science* 313 (5788), 803–807.

LÉZINE, A.-M., ZHENG, W., BRACONNOT, P., KRINNER, G. 2011: Late Holocene plant and climate evolution at Lake Yoa, northern Chad: pollen data and climate simulations. *Climate of the Past Past* 7, 1351–1362.

LUCARINI, G. 2013: Was a transition to food production homogeneous along the circum-Mediterranean littoral? A perspective on Neolithization research from the Libyan coast. In: Shirai, N. (Ed.): *Neolithisation of Northeastern Africa*. Studies in Early Near Eastern Production, Subsistence, and Environment 16, Berlin, 149–173.

MALEY, J. 1981: *Etudes palynologiques dans le bassin du Tchad et paléoclimatologie de l'Afrique nord-tropicale de 30 000 ans à l'époque actuelle*. Travaux et documents de l'ORSTOM 129, Paris.

MALEY, J. 2010: Climate and Palaeoenvironment evolution in north tropical Africa from the end of the Tertiary to the Upper Quaternary. *Palaeoecology of Africa* 30, 227–278.

MALEY, J., VERNET, R., 2013: Peuples et évolution climatique en Afrique nord-tropicale, de la fin du Néolithique à l'aube de l'époque moderne. *Afriques, débats, méthodes et terrains d'histoire*. Volume 4. Journal électronique édité par le CLÉO – Centre pour l'édition électronique ouverte, France. DOI:10.4000/afriques.1209.

MANDAVILLE, J. P. 2011: *Bedouin Ethnobotany: Plant Concepts and Uses in a Desert Pastoral World*. University of Arizona Press, Tucson, USA.

MEDEANIC, S. 2006: The palynomorphs from surface sediments of intertidal marshes in the estuarine part of the Patos Lagoon. *Iheringia, sér. Botânica* 61 (1–2), 49–62.

MERCURI, A. M. 2008a: Human influence, plant landscape, evolution and climate inferences from the archaeobotanical records of the Wadi Teshuinat area (Libyan Sahara). *Journal of Arid Environments* 72, 1950–1967.

MERCURI, A. M. 2008b: Plant exploitation and ethnopalynological evidence from the Wadi Teshuinat area (Tadrart Acacus, Libyan Sahara). *Journal of Archaeological Science* 35 (6), 1619–1642.

MERCURI, A. M. 2014: Genesis and evolution of the cultural landscape in central Mediterranean: the "where, when and how" through the palynological approach. *Landscape Ecology* 29, 1799–1810.

MERCURI, A. M. 2015: Applied palynology as a trans-disciplinary science: the contribution of aerobiology data to forensic and palaeoenvironmental issues. *Aerobiologia 31*, 323–339.

MERCURI, A. M., BANDINI MAZZANTI, M., TORRI, P., VIGLIOTTI, L., BOSI, G., FLORENZANO, A., OLMI, L., MASSAMBA N'SIALA, I. 2012: A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po valley as a result of human impact and climate change. *Vegetation History and Archaeobotany* 21, 353–372.

MERCURI, A. M., MASSAMBA N'SIALA, I., FLORENZANO, A. 2013: Environmental and ethnobotanical data inferred from pollen of Gobero and the dried lakebeds in the surrounding area. In: Garcea, E. A. A. (Ed.): *Gobero: The No-Return Frontier. Archaeology and Landscape at the Saharo-Sahelian Borderland.* Journal of African Archaeology Monograph Series 9. Africa Magna Verlag, Frankfurt, 81–104.

MERCURI, A. M, SADORI, L., UZQUIANO OLLERO, P. 2011: Mediterranean and north-African cultural adaptations to mid-Holocene environmental and climatic change. *The Holocene* 21, 189–206.

MIGLIORE, J., BAUMEL, A., JUIN, M., FADY, B., ROIG, A. *et al.* 2013: Surviving in Mountain Climate Refugia: New Insights from the Genetic Diversity and Structure of the Relict Shrub *Myrtus nivellei* (Myrtaceae) in the Sahara Desert. *PLoS ONE* 8 (9), e73795. DOI:10.1371/journal.pone.0073795.

MUDIE, P. J., MARRET, F., ROCHON, A., AKSU, A. E. 2010: Non-pollen palynomorphs in the Black Sea corridor. *Vegetation History and Archaeobotany* 19, 531–544.

NOË, R., BLOM, C. W. P. M. 1981: Occurrence of three *Plantago* species in coastal dune grasslands in relation to pore-volume and organic matter content of the soil. *Journal of Applied Ecology* 19, 177–182.

QUÉZEL, P. 1997: High mountains of the Central Sahara: dispersal, speciation, origin and conservation of the flora. In: Barakat, H. N., Hegazy, A. K. (Eds.): *Reviews in Ecology: desert conservation and development*. Metropole, Cairo, 159–175.

QUÉZEL, P, MARTINEZ, C. 1960: Le dernier interpluvial au Sahara central, essai de chronologie palynologique et paléoclimatique. *Lybica* 6/7, 211–227.

ROBERTS, N., BRAYSHAW, D., KUZUCUOGLU, C. 2011: The mid-Holocene climatic transition in the Mediterranean: causes and consequences. *Holocene* 21 (1), 3–13.

SADORI, L., MASI, A., RICOTTA, C. 2015: Climate-driven past fires in central Sicily. *Plant Biosystems* 149 (1), 166–173.

SERENO, P. C., GARCEA, E. A. A., JOUSSE, H., STOJANOWSKI, C. M., SALIÈGE, J.-F., MAGA, A., IDE, O. A., *ET AL.* 2008: Lakeside Cemeteries in the Sahara: 5000 Years of Holocene Populations and Environmental Change. *PLoS ONE* 3 (8), 1–22. e2995.

SMITH, M., VETH, P., HISCOCK, P., WALLIS, L. A. 2005: Global Deserts in Perspective. In: Veth, P., Smith, M., Hiscock, P. (Eds.): *Desert Peoples: Archaeological Perspectives*. Blackwell, Oxford, 1–13.

SWEZEY, C., LANCASTER, N., KOKUREK, G., DEYNOUX, M., BLUM, M., PRICE, D., PION, J.-C. 1999: Response of aeolian systems to Holocene climatic and hydrologic changes on the northern margin of the Sahara: A high-resolution record from the Chott Rharsa basin, Tunisia. *The Holocene* 9 (2), 141–147.

VALE, C. G, PIMM, S. L, BRITO, J. C. 2015: Overlooked Mountain Rock Pools in Deserts Are Critical Local Hotspots of Biodiversity. *PLoS ONE* 10 (2), e0118367. DOI:10.1371/journal.pone.0118367.

VAN DER KAARS, S., PENNY, D., TIBBY, J., FLUIN, J., DAM, R., SUPARAN, P. 2001: Late quaternary palaeoecology, palynology and palaeolimnology of a tropical lowland swamp: Rawa Danau, West Java, Indonesia. P*alaeogeography, Palaeoclimatology, Palaeoecology* 171, 185–212.

VAN GEEL, B. 2001: Non-pollen palynomorphs. In: Smol, J. P., Birks, H. J. B., Last, W. M. (Eds.): *Tracking environmental change using lake sediments, Vol 3: Terrestrial, algal and silicious indicators*. Kluwer, Dordrecht, 99–119.

WATRIN, J., LÉZINE A. M., HÉLY, C. 2009: Plant migration and plant communities at the time of the "green Sahara". *C R Geoscience* 341, 656–670.

WHITE, F. 1983: *The vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*. UNESCO, Paris, France.