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Abstract

The littoral site of Ifri Oudadane is one of the most important recently excavated sites in the Mediterranean Maghreb. The shelter presents Epipalaeolithic and Neolithic layers and therefore offers the possibility to investigate the Neolithic transition in the region. Besides introducing the archaeological context, this paper focuses on palaeobotanical data in order to reconstruct Holocene environmental change and human use of plant resources for the period c. 11 to 5.7 ka cal. BP. Results show intense landscape transformations resulting from anthropic and climatic factors. First human occupations start at the beginning of the Holocene with favourable conditions in this otherwise harsh semi-arid stretch of land. A wooded environment with evergreen sclerophyllous oaks and riparian forests is documented and exploited by hunter-gatherers. From c. 7.6 ka cal. BP farming activities are well attested together with significant human impact, herding pressure and a progressive decline of arboreal components. After 6.6 ka cal. BP conditions become less favourable and markers for aridity increase. Riparian taxa disappear (*Alnus*) or decrease (*Fraxinus, Populus, Salix*); shrubs (*Tamarix*) and grasses (*Artemisia*) increase with a degradation of forest into shrubland (macchia). During 6.6 and 6.0 ka cal. BP there is a general occupation gap in arid and semi-arid Morocco and evidence for that change is also found in the alluvial deposits of the Moulouya, NE Morocco. Indicators for food production decrease at the same time and the site is abandoned during the first half of the 6th millennium cal. BP.

Keywords

agriculture, aridity, charcoal, Morocco, Neolithic, pollen

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Introduction

The Epipalaeolithic–Neolithic transition of the Western Mediterranean has been a controversial topic in archaeological research. Investigations have recently received new input in the fields of chronology (Carvalho Faustino, 2010; Linstädter and Kehl, 2012), the appearance and development of pottery (Bernabeu et al., 2011; Garcia et al., 2011), the formation of regional groups (Manen et al., 2010) and the issue of raw material supply (Binder et al., 2010; Linstädter and Müller-Sigmund, 2012). Altogether studies attest that the previous model of a temporal gradient between Europe and Africa resulting in unidirectional cultural influence from north to south is no longer sustainable (Ammerman and Cavalli-Sforza, 1973; Roudil, 1990). New models of transition have evolved proposing network-based interactions that include an African impact on the European Neolithisation process (Linstädter et al., 2012; Manen et al., 2007). However, besides topics concerning chronology and the development of material culture, particular attention has been paid to the reconstruction of the palaeoenvironment (López-Sáez et al., 2010, 2011), human–environment interaction (Carrión et al., 2010; López-Sáez and López-Merino, 2008) and the possible impact of environmental change on the formation of early-Neolithic societies (Cortés et al., 2012; Shipp et al., 2013). On the basis of new pollen and wood charcoal data from Ifri Oudadane, this paper focuses on the reconstruction of the palaeoenvironment, early agriculture and gathering activities, human impact on the landscape with the onset of the Neolithic, and the effect of climatic degradation from the Epipalaeolithic from c. 11 ka cal. BP up to the late Neolithic c. 5.7 ka cal. BP. Results from the analysis of plant macroremains other than charcoal will also be taken into consideration in the discussion (Morales et al., 2013).

As already argued elsewhere (Linstädter et al., 2012), semi-arid NE Morocco is a very vulnerable region where environmental changes affect prehistoric humans more directly than in more temperate zones. Diverse climate and environmental archives from marine cores off the Moroccan coasts (Berger and Guilaine, 2009; Cacho et al., 2001; Combourieu Nebou et al., 1999, 2009; Rodrigo-Gámiz et al., 2011) show such shifts in temperature and humidity during the early and mid Holocene. However, the situation of global marine ecosystems cannot be directly transferred to the

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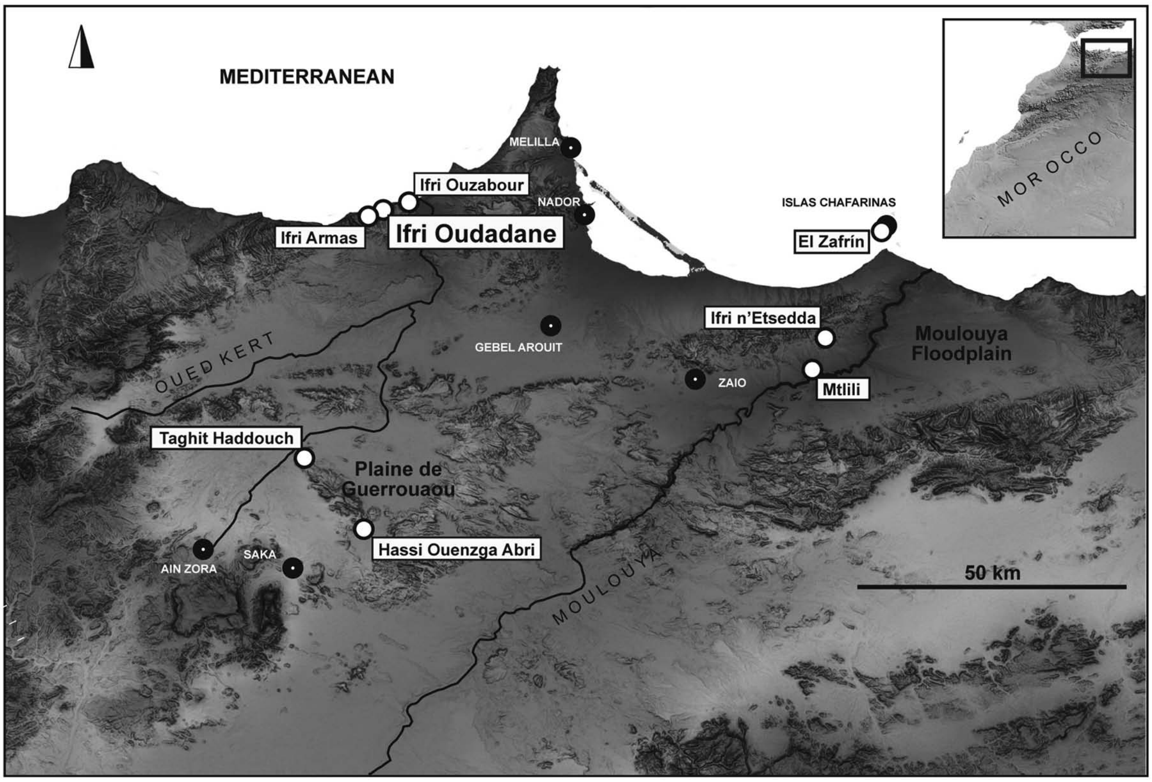

Figure 1. Location of Ifri Oudadane and other relevant archaeological sites in their Western Mediterranean context (NE Morocco).

mainland and effects on human occupation are hard to estimate. To determine the impact of global or regional climate on environmental change, data from terrestrial archives are needed. These data reflect on one hand the effect of supra-regional environmental changes on terrestrial ecosystems and stem, on the other hand, from locations closer to human living sites. This ideal constellation of anthropogenic deposits embedded in environmental archives has recently been investigated in the overbank sediments of the Lower Moulouya River south of the Melilla Peninsula (Ibouhouten et al., 2010; Linstädter et al., 2012). This paper focuses on palaeobotanical proxies retrieved from the archaeological site of Ifri Oudadane. These assemblages, in spite of similarities, may provide different sets of data. In the case of pollen and charcoal, differential pollen rain, human selection of plant resources and different catchment area are some of the issues that may explain dissimilarities. Pollen analysis reflects vegetation change on a local and regional level – notwithstanding the limitations that pollen analysis from caves and rock shelters may pose (see among others, Navarro et al., 2000, 2001). Wood charcoal analysis on the other hand tends to provide very local information on species occurrence and woodland composition. On archaeological sites charcoal can be human biased because of the potential selection of certain species for fire or craft making. But also because of this it is an invaluable tool to assess human action over natural woodlands. Combining pollen and wood charcoal – pollen and macroremains in general (Birks and Birks, 2000) – compensates biases and strengthens interpretations on vegetation composition and dynamics on a local, extra-local and regional scale (Nelle et al., 2010). On-site pollen and wood charcoal analyses from northwest African Epipalaeolithic and Neolithic sites are rare (López-Sáez and López-Merino, 2008). Pollen analyses are available from Kaf Taht el-Ghar (Ballouche and Marinval, 2003, 2004) and from Chafarinas Islands (López-Sáez et al., 2010). Anthracological analyses are available from Moulouya open air sites (Linstädter et al., 2012) and from Benzú rock shelter (Ramos et al., 2007: 32).

Today's climate in the area is a Mediterranean one with precipitation between autumn and spring, a result of the southwards-migrating westerlies (Allen, 1996: 308). Rain is mostly restricted to the coastal areas and declines rapidly southwards (Guersif: 192 mm/yr). The mountains show an increase of precipitation by increasing altitude (up to 500 mm/yr) and a decrease of annual average temperature (Ngadi, 1995). Average temperature in winter is below 15°C. Summer climate is dominated by the northwards-migrating subtropical high pressure cell. The accompanying high temperatures and rare rains cause droughts from time to time (Allen, 1996: 307). The position of the Maghreb between the temperate and subtropical Hadley cells together with the Atlantic and continental influences induce a very complex climate regime with many shifts through time. From a biogeographic view the area is located in the semi-arid thermo-Mediterranean zone (Sauvage, 1963), with a corresponding vegetation of drier forests of arar tree (*Tetraclinis articulata*) with kermes oak (*Quercus coccifera*) and *Pistacia lentiscus* (*Tetraclino articulatae-Quercetum cocciferae*), along with an abundance of wild olive trees (*Olea europaea*) and other thermophilous elements such as *Ceratonia siliqua, Juniperus phoenicea, Chamaerops humilis, Rhamnus lycioides, Smilax aspera*, etc. (Benabid and Fennane, 1994). Mesomediterranean forests at higher altitudes of the region correspond to sclerophyllous evergreen oaks characterized by the predominance of the holm oak (*Quercus ilex*) and pines (*Pinus halepensis*) while in wetter areas and deeper soils the cork oak appears (*Quercus suber*). Riparian forests are related to *Fraxinus angustifolia* and *Populus alba* formations (Benabid, 1984, 2000; Charco, 1999, 2001).

Ifri Oudadane

The site of Ifri Oudadane is located in a coastal cliff of marble, about 50 m above the present-day shoreline (Figures 1, 2). Today the shelter is cut from the adjacent mountain range by a recently built coastal road. The immediate surroundings of the site are covered by the road debris and the former topography is hard to imagine. To the south, the terrain rises steeply to plateaus that rise up to 150 m above sea level. The Ifri Oudadane rock shelter is some 5 m high, 15 m wide and formed by marine abrasion during a former high-stand in sea level. The 2 m thick archaeological deposit covers a time span of more than 5000 years, documented with 18 radiocarbon ages (Table 1), and shows records from the Epipalaeolithic c. 11 ka cal. BP up to the late Neolithic c. 5.7 ka cal. BP. A full Neolithic record, including domesticated animals and cereals, is documented from 7.6 ka cal. BP onwards. The sedimentary deposits of the site accumulated mostly through anthropogenic processes and particularly significant is the transition from more a homogeneous sediment at the bottom, representing the Epipalaeolithic, to 'fumier-like' sediment on top (see Angelucci et al., 2009), formed during the Neolithic occupation. The combination of sedimentological, geochemical and micromorphological analyses together with the distribution of archaeological material – pottery, lithic industries, raw material supply – and radiocarbon data provide a subdivision into five human occupation phases (Linstädter and Kehl, 2012). The occupation starts with the Epipalaeolithic at around 11 ka cal. BP. The up to 1 m thick deposit represents the last hunter-gatherer society of the region. In addition to remains associated with hunting and gathering activities, the archaeological assemblage provides substantial evidence for the exploitation of maritime resources, including fishing and the collection of sea shells. The sparse lithic material consists mainly of unspecific flakes as well as some notched flakes and blades, scrapers and typical Epipalaeolithic backed points. The oldest Neolithic data and the youngest Epipalaeolithic radiocarbon dating (7632±29 cal. BP, Beta 316137, made of a *Chamaeorops humilis* sample) suggest a continuous occupation of the site. The following early Neolithic is subdivided into three phases: Early Neolithic A to C (ENA, ENB, ENC). The most characteristic feature here is the presence of ashy or charcoal-rich layers, the result of extensive burning practices alternating with artefact-rich layers and including herbivore coprolites which reflect the use of the site for penning ovicaprids, a common activity during the Neolithic in the Mediterranean world that results in the formation of this type of cave deposits (Angelucci et al., 2009). The initial ENA, only present in the northern part of the excavation area, starts at 7.6 cal. BP and is characterised by the appearance of Cardium-decorated pottery and large notched blades indicating changes in lithic tool production. An emerging bone industry is documented by the occurrence of bone needles. The most remarkable change is the appearance of domesticated animals and plants that mark a more diversified subsistence strategy. The use of maritime resources is still important during the early Neolithic. An increased accumulation rate in this period suggests a more dynamic occupation of the shelter. The following ENB can be considered the main occupation phase represented across the entire excavation. Most of the radiocarbon dates are made on short-lived samples of cereals and legumes and date that phase between 7.1 and 6.7 ka cal. BP (Table 1). Accumulation rate increases again and calcite spherulites document intensive penning of ovicaprides inside the shelter. The archaeological material is rather rich. ENA and ENB can be clearly distinguished from one another on the basis of pottery decoration (Linstädter and Kehl, 2012). The ENC dated between 6.6 and 6.3 ka cal. BP is characterised by only a shallow deposit and few finds suggesting a decline of settlement intensity. Ifri Oudadane

Figure 2. Ifri Oudadane view from the east. Ancient surface before covered by road work debris.

Table 1. Results of radiocarbon dating on bone, charcoal and seeds from Ifri Oudadane.

Lab. no.	^{14}C age	Cal. BP	δ^{13}C ‰ PDB	Material	Taxon	Phase	Position
KIA 39296	5000±30	5763±80	−25.12	Charcoal	*Juniperus sp.*	LN	Pos. 116
Beta 295772	5590±40	6370±40	−231.9	Cereal	*Triticum dicoccum*	ENC	Pos. 487
Beta 295777	5670±40	6460±40	−19.2	Cereal	*Hordeum vulgare*	ENC	Pos. 764
Erl 9987	5756±49	6563±62	−22.9	Charcoal	*Juniperus sp.*	ENC	Pos. 11
Beta 295776	5900±40	6730±50	−23.6	Cereal	*Triticum dicoccum*	ENB	Pos. 678
Beta 295775	5910±40	6740±50	−22.6	Cereal	*Triticum* indet.	ENB	Pos. 635
Beta 295778	5930±40	6760±50	−23.0	Pulse	*Pisum sativum*	ENB	Pos. 766
Beta 295773	5980±40	6820±60	−25.0	Cereal	*Hordeum vulgare*	ENB	Pos. 520
Beta 295774	5980±40	6820±60	−20.8	Cereal	*Hordeum vulgare*	ENB	Pos. 537
Oxa 23528	6136±34	6907±70	–	Bone	*Capra hircus*	ENB	Pos. 354
KIA 39297	6155±30	6951±33	−19.55	Charcoal	*Juniperus sp.*	ENB	Pos. 258
Erl 9989	6053±50	7058±76	−23.8	Charcoal	*Olea* sp.	ENB	Pos. 42
Erl 9988	6175±50	7074±63	−23.9	Charcoal	*Juniperus sp.*	ENB	Pos. 31
KIA 39298	6085±25	7081±70	−20.99	Charcoal	*Juniperus sp.*	ENB	Pos. 274
Beta- 318608	6140±30	7063±73	–	Cereal	*Triticum* sp.	ENB	Pos. 835
KIA 39299	6400±90	7327±81	−24.68	Charcoal	*Juniperus sp.*	ENA	Pos. 343
Beta 295779	6740±50	7610±40	n.m.	Pulse	*Lens culinaris*	ENA	Pos. 860
Beta- 316137	6780±40	7632±29	−20.1	Seed	*Chamaerops humilis*	EPI	Pos. 890
Beta- 313467	7150±40	7979±25	−20.8	Seed	*Chamaerops humilis*	EPI	Pos. 945
Erl 12419	7451±56	8278±61	−17	Bone	*Sus scrofa*	EPI	Pos. 381
Beta- 313468	8080±40	9028±41	−18.4	Seed	*Chamaerops humilis*	EPI	Pos. 989
Erl 12418	9496±183	10,810±262	−23.9	Bone	*Ammothragus lervia*	EPI	Pos. 352

Note: n.m.: not measurable.

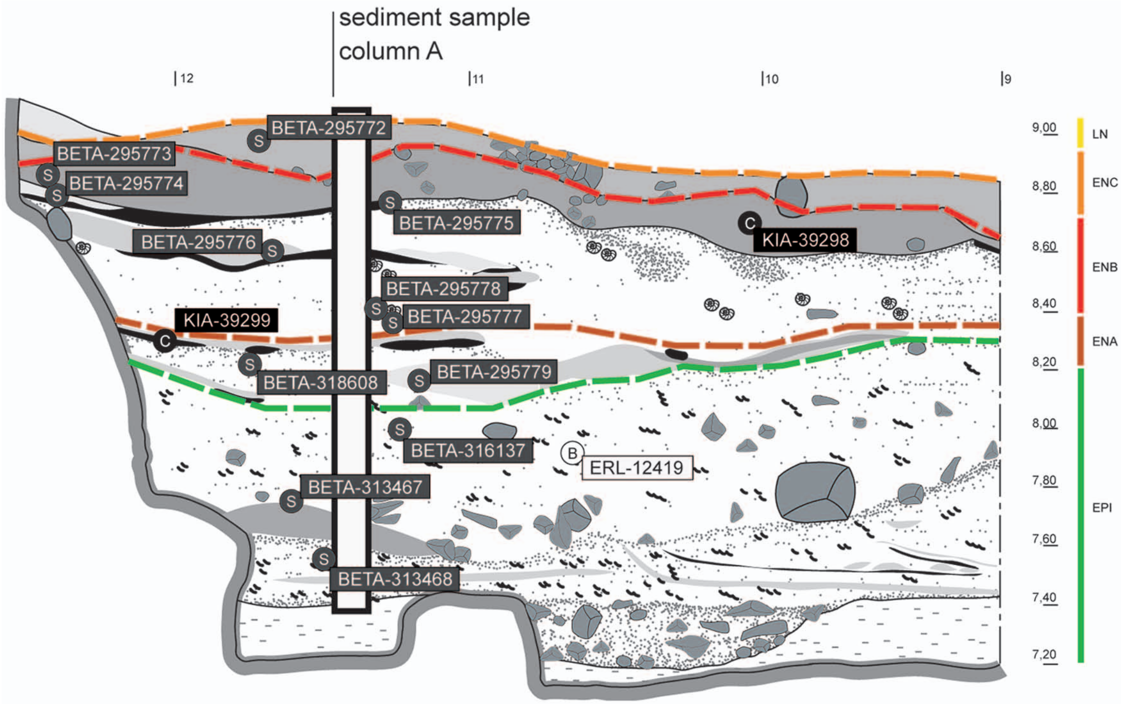

Figure 3. Archaeological sequence of Ifri Oudadane with the location of radiocarbon-dated material (Table 2). Material dated: B: bone; C: wood charcoal; S: seed. Column A marks the area sampled for pollen.

occupations end during the first half of the 6th millennium cal. BP. The last late-Neolithic materials are to be found scattered on the surface not sufficient to form a proper layer. The charcoal sample which yielded an age of 5763±80 cal. BP (KIA 39296) fits well with the late Neolithic of the area (Linstädter, 2008).

The palaeobotanical record from Ifri Oudadane in this paper aims to: (1) reconstruct the palaeo-environment, particularly the vegetation dynamics, during the prehistoric occupation between 11.0 and 5.7 ka cal. BP, (2) identify human use of plant resources, (3) assess human impact on the surrounding area, and (4) examine whether changes in the archaeological record such as the Epipalaeolithic–Neolithic transition or the abandonment of the site coincide with environmental shifts documented in the deposit; we should not forget that, in comparison with other areas of the Mediterranean world, the site is located in a semi-arid environment, particularly sensitive to climate change.

Material and methods

Sampling

Sedimentological and pollen samples were obtained from two profiles, CE (column A) and FB (column B). Both columns were sampled from bottom to top in intervals of 5 cm, taking care not to mix macroscopic visible layers or structures. For the pollen analysis presented here, only the 23 samples from profile A are considered. (Figure 3). Samples for plant macroremains were taken from every artificial layer during the excavation. For wood charcoal analysis, 57 samples retrieved through flotation have been analyzed. Wood in these samples was scattered through the sediment, it was not concentrated charcoal or charcoal from hearths. In order to obtain a significant number of specimens, samples have been grouped by chronology in four periods (Epipalaeolithic, Early Neolithic A, Early Neolithic B and Early Neolithic C).

Pollen analysis

An average of 20 g of sediment was chemically treated to remove the mineral fractions. The method followed for pollen and non-pollen palynomorphs (NPPs) extraction is that described by Burjachs et al. (2003), where palynomorphs were concentrated using Thoulet liquor (Goeury and de Beaulieu, 1979). The final residue was suspended in glycerine and counted until a pollen sum of 250 grains was reached, excluding NPPs and anthropogenic taxa such Cichorioideae, Cardueae and *Aster* type (Bottema, 1975; Carrión, 1992; López-Sáez et al., 2003). Slides were examined with a light microscope using a magnification of 400× or 1000×. Pollen taxonomy follows Valdés et al. (1987), Moore et al. (1991) and Reille (1992, 1995). *Cerealia* type was defined as Poaceae exceeding 45 µm with a minimum annulus diameter of 8–10 µm (Beug, 2004; López-Sáez and López-Merino, 2005). The majority of NPPs present on the pollen slides were identified and their nomenclature conforms to van Geel (2001). Diagrams were drawn using Tilia 2.0 and TGView (Grimm, 1992, 2004). Pollen analysis was undertaken at the Archaeobotany Laboratory (CCHS, CSIC, Madrid).

Wood charcoal analysis

Preservation of wood macroremains on the site has taken place by charring as it is common in archaeological contexts from the Western Mediterranean. Anatomical analysis of wood charcoal has been carried out at the Archaeobotany Laboratory (CCHS, CSIC, Madrid) with an incident-light microscope Leica DM 4000M (50×/100×/200×/500×). Transversal and longitudinal radial and tangential sections of the specimens have been observed. The identification has been done through comparison of the anatomical features with a modern reference collection and with different atlases (Neumann et al., 2001; Schweingruber, 1990; Vernet et al., 2001).

Results

Pollen analysis

An overall good state preservation of pollen grains and NPPs was found in Ifri Oudadane. Total pollen and NPP percentages are given in Figures 4 and 5. The Epipalaeolithic levels (7.35–8.10 m depth) are characterized by high percentages of trees

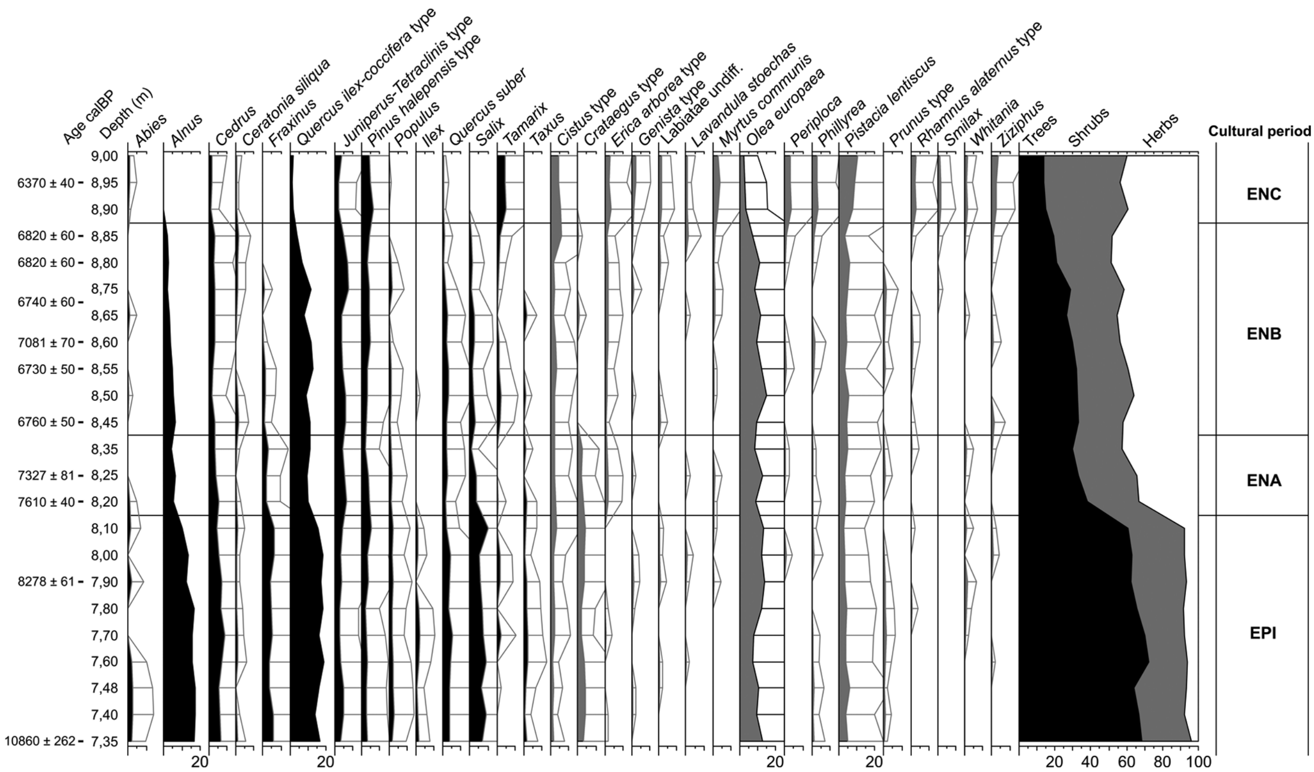

Figure 4. Pollen diagram from Ifri Oudadane including tree and shrub data.

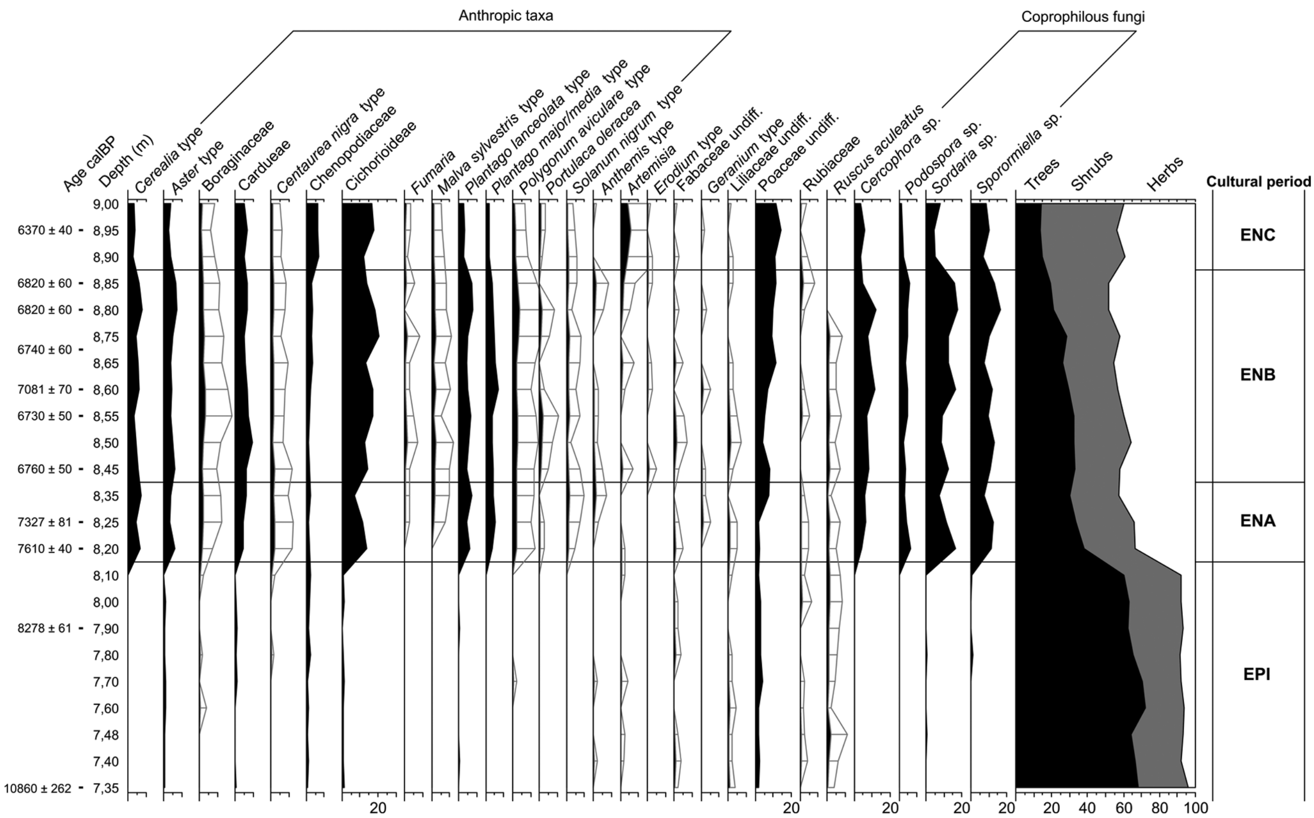

Figure 5. Pollen diagram from Ifri Oudadane. Non-arboreal pollen including anthropic taxa and non-pollen palynomorphs (NPPs) of coprophilous fungi.

(60.5–72.1%). The arboreal pollen assemblage is dominated by *Quercus ilex-coccifera* type (14–18.7%), *Alnus* (10–17.5%) and *Sali*x (5.4–10%), indicating the establishment of evergreen sclerophyllous oak (holm and/or kermes oak) and riparian (alder and willow) forests in the surroundings of the site. Other elements such as *Abies* (0–2.7%), *Cedrus* (4.3–7.1%), *Quercus suber* (1.9–5.6%), *Taxus* (0.8–2.5%), *Ilex* (0–2.2%) and *Pinus halepensis* type (1.9–5.2%) have probably a regional or extra-regional origin, while *Ceratonia siliqua* (0–1.2%) and *Juniperus-Tetraclinis* type (2.6–4.9%) are part of oak forests and

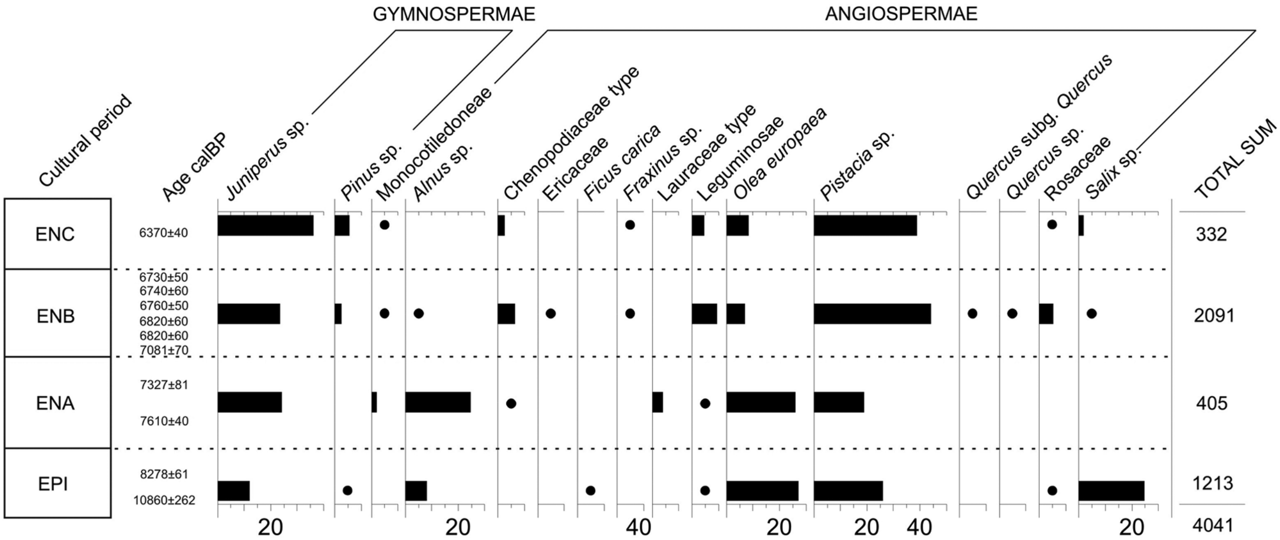

Figure 6. Charcoal histogram from Ifri Oudadane (*n* = 4041 wood fragments).

Fraxinus (3.7–6.6%), *Populus* (1.6–2.8%) and *Tamarix* (0–2.2%) of the riparian one. The shrub vegetation (21.5–31.4%) shows a remarkable importance, with a good representation of the xerothermophilous macchia mainly composed of *Olea europaea* (7.1–13.6%) and *Pistacia lentiscus* (2.9–5.8%), as well as *Myrtus communis, Phillyrea, Rhamnus alaternus* type, *Cistus* type, *Erica arborea* type and *Genista* type. *Crataegus* type (1.7–4.3%) and *Prunus* type (0–1.3%) are represented, while other species of the thermal flora (*Periploca, Whitania, Ziziphus*) are also present sporadically (c. 1%). Among the herbs (4.2–8.3%), only Poaceae (1.8–3.9%) and *Ruscus aculeatus* (0.4–1.6%) show noticeable values. Anthropogenic types (*Aster*, Boraginaceae, Cardueae, Cichorioideae, *Centaurea nigra*) are also present at very low amounts (<1.3%), while pastoral indicators such as Chenopodiaceae, *Plantago* sp., *Polygonum aviculare*, and the coprophilous fungi *Cercophora, Sordaria, Sporormiella* and *Podospora* account for less than 1%.

The Early Neolithic A and B (ENA: 8.20–8.35 m depth and ENB: 8.45–8.85 m depth) levels show a general decrease in arboreal pollen (30.1–38.2% ENA, 19.4–33.2% ENB). Extra-regional or regional taxa mentioned above are still present but in lower percentages (holly and yew disappear at the top of ENB). In these levels, significant oscillations and decreasing values of *Quercus ilex-coccifera* type (7–12.8%) are noticed, reaching 3.9% at 8.85 m. *Ceratonia siliqua* and *Juniperus-Tetraclinis* type follow an opposite pattern (0–1.7% and 4.3–7.7%, respectively). Riparian forest (*Alnus, Fraxinus, Populus, Salix*) declines progressively – alder (2.2–6.5%), willow (1–3.9%), ash and poplar dissapear in the samples above – while *Tamarix* (0–2.4%) increases. Among the shrubs (24.5–32.3%), *Olea europaea* (7.2–14.6%) and *Pistacia lentiscus* (3.3–5.9%) continue to be relatively abundant while the other elements of the xerothermophilous macchia continue being present. Only *Erica arborea* type (0.5–2%) slightly increases, while *Crataegus* type experience a decreasing tendence not being present in many samples of the ENB. *Smilax* (c. 0.6%) appears at the end of the ENB. Anthropic types such as *Aster* (3.5–7.5%), Boraginaceae (1.5–3.6%), Cardueae (4.4–9.9%), Cichorioideae (7.2–20.3%), *Centaurea nigra* (1.1–2.5%), *Malva sylvestris* (0–2.4%), *Portulaca oleracea* (0–2.1%), *Solanum nigrum* (0.5–1.9%) and *Fumaria* (0–1.6%) show significant values, as well as pastoral indicators (*Plantago lanceolata* 4.3–8.1%, *Plantago major/media* 3.5–6.8%, *Polygonum aviculare* 2–3.8%, Chenopodiaceae 1.4–3.5%) and coprophilous fungi (*Cercophora* 4.4–12.4%, *Sordaria* 7.2–17.7%, *Sporormiella* 7.2–16.7%, *Podospora* 2.4–6.4%). Poaceae show very high values (2–11.7%). *Cerealia* pollen is attested in all samples from the ENA and ENB levels, with rates of 4.5–7.2% in the ENA and 3.6–8.1% during the ENB.

The Early Neolithic C levels (8.90–9.00 m depth) show a general increase in shrub pollen percentages, reaching maximum values close to 47%. The shrub pollen assemblage is dominated by *Pistacia lentiscus* (7.9–10.4%), *Erica arborea* type (2.4–3.7%), *Myrtus communis* (3.0–3.9%), *Genista* type (1.4–2.1%), *Lavandula stoecha*s (0.6–1%), *Smilax* (1.3–2%), *Rhamnus alaternus* type (2.4–3.1%), *Whitania* (0.9–1.4%), *Ziziphus* (2.4–3.7%), *Periploca* (3–3.7%), *Phillyrea* (2.7–3.7%), *Cistus* type (4.3–5.4%) and Labiatae undiff. (1.3–1.7%), indicating the establishment of a xerothermophilous macchia in the area at the expense of some local arboreal elements c. 14–15% (*Quercus ilex-coccifera* type 1.2–1.7%, *Juniperus-Tetraclinis* type 2.3–3.7%, *Ceratonia siliqua* 0.3–0.7%) and *Olea europaea* (2–3.1%). Extra-regional or regional taxa such *Abies* (0.3–0.9%), *Cedrus* (1.1–2%) or *Quercus suber* (0.3–0.6%) are still present but with decreasing values, while *Pinus halepensis* type (4.4–6.2%) remains constant. Riparian taxa such as *Alnus* or *Fraxinus* disappear and *Populus* is present in a single sample (8.95 m) with very low values (0.3%), whereas *Tamarix* is at its maximum percentages in the ENC levels (4.4–5.1%). In addition, the record also shows higher values of *Artemisia* (4.2–5.7%), probably indicating drier conditions. The herbaceous component (39.6–43.5%) is dominated by grass pollen (11–14.5%) and continuous values of a set of herbaceous pollen taxa related to human activities (*Aster*, Boraginaceae, Cardueae, Cichorioideae, *Centaurea nigra, Malva sylvestris, Portulaca oleracea, Solanum nigrum, Fumaria, Plantago lanceolata, P. major/media, Polygonum aviculare*, Chenopodiaceae). In the ENC levels there is a small decline in coprophilous fungi (*Cercophora, Sordaria, Sporormiella, Podospora*) and *Cerealia* type (2.5–3.9%) percentages with respect to the previous ENA and ENB levels.

Charcoal analysis

A total of 4196 wood fragments have been analyzed and 4041 (96.3%) have been identified (Figure 6). Fragments not identified correspond to specimens with anatomical alterations so diagnostic features could not be observed. Charcoal identified in Ifri Oudadane corresponds to 15 taxa, conifers (*Juniperus* sp. and *Pinus* sp.) and angiosperms (*Alnus*, Chenopodiaceae tp., Ericaceae, *Ficus carica, Fraxinus* sp., Lauraceae tp., Fabaceae, Monocotiledoneae, *Olea europaea, Pistacia* sp., *Quercus* subg.

Quercus, Rosaceae and *Salix* sp.). Within the gymnosperms, although there are limitations for the anatomical discrimination between the genera *Juniperus* and *Tetraclinis* particularly in poorly preserved charred archaeological material, the presence of short rays in tangential section in the material from IOD points to the genus *Juniperus* rather than *Tetraclinis*. In terms of the presence and absence of taxa, the Early Neolithic B shows the highest diversity but this could be due to the high number of fragments that have been identified for this period (2091) something that usually results in the representation of rare taxa (in this case *Quercus* for example) which otherwise would be absent. Regarding the presence/absence of taxa and their relative importance, we can see some continuity and some differences between the Epipalaeolithic and the Neolithic levels. During the Epipalaeolithic, according to fragment number, three taxa are the most common woods used on the site with similar percentages – *Olea* (27.2%), *Pistacia* (26%) and *Salix* (24.6%). *Juniperus* (11.9%) and *Alnus* (8.2%) are well represented and other types of wood are completely minor (< 1%) (*Ficus*, Fabaceae, *Pinus*, Rosaceae). During the Early Neolithic A *Salix* disappears and *Juniperus* (24.2%), *Alnus* (24.7%) and *Olea* (25.9%) are the main taxa with very similar percentages. *Pistacia* slightly decreases (18.8%). The other four taxa are minor: Monocotiledoneae (2%), Fabaceae (0.25%), Chenopodiaceae tp. (0.25%) and Lauraceae tp. (3.95%). During the Early Neolithic B the most significant changes are the virtual disappearance of *Alnus* (0.8%), the decrease of *Olea* (6.9%) and the increase in the use of *Pistacia* (44.1%). *Juniperus* (23.4%) continues being a very important fuel and Chenopodiaceae tp. (6.3%) and Fabaceae (9.3%) increase. Monocotiledoneae (0.8%) continue being slightly used. Other taxa reappear (*Pinus* 2.5%, *Salix* 0.1%) or appear for the first time with a low representation: Ericaceae (0.2%), *Fraxinus* (0.05%), deciduous *Quercus* (0.05%) and *Quercus* (0.1%), Rosaceae (5.2%). During the Early Neolithic C the general pattern is similar to the previous assemblage although *Juniperus* (36.1%) use increases and *Pistacia* (38.8%) slightly decreases. *Olea* (8.4%), *Pinus* (5.4%) and Fabaceae (4.5%), continue being used and the other taxa are rare: Chenopodiaceae tp. (2.4%), *Fraxinus* (0.9%), Monocotiledoneae (0.6%), Rosaceae (0.9%), *Salix* (1.8%).

Other plant macrorremains

Results from the macrobotanical analysis indicate that wild plants were abundantly collected by humans in both the Epipalaeolithic and the early-Neolithic periods. Among them, *Pistacia lentiscus, Chamaerops humilis, Lathryus/Vicia* sp., *Olea europaea, Quercus* sp. and *Juniperus phoenicea* are the most frequent. Domesticated plants such as cereals (*Hordeum vulgare, Triticum monococcum/dicoccum, Triticum durum* and *Triticum aestivum/durum*) and pulses (*Lens culinaris* and *Pisum sativum*) are present from the early-Neolithic levels together with a group of arable weeds (Table 2). One lentil has been dated to 7610 ± 40 cal. BP (Beta 295779), representing the oldest direct date of a domesticated plant seed in Morocco and, by extension, in North Africa. In addition to fruits and seeds that could have been consumed by both humans and domesticated animals, fragments of esparto grass (*Stipa tenacissima*) rhizomes have been identified. This is a western Mediterranean native plant that may have been used as a source of fibers for basketry (Morales et al., 2013).

Table 2. Plant macroremains other than wood from Ifri Oudadane.

Archaeological level	Epipalaeolithic	Early Neolithic	Total
Number of samples	46	114	160
Volume sediment (l)	691	1631	2322
Cultivated plants			
Triticum monococcum/dicoccum, seed (einkorn/ emmer)		1	1
Triticum durum, rachis segment (hard wheat)		1	1
Triticum aestivum/durum, seed (free threshing wheat)		7	7
Triticum sp., seed (indeterminated wheat)		9	9
Hordeum vulgare, seed (barley)		31	31
Cereal indet.		10	10
Lens culinaris (lentil)		1	1
Pisum sativum (pea)		1	1
Wild plants			
Chamaerops humilis (dwarf fan palm)	53	89	142
cf. Cistaceae capsule		1	1
Fabaceae	14	30	44
Juniperus phoenicea (juniper)		33	33
Lathyrus/ Vicia sp. (wild pulse)	13	36	49
Myrtus communis (myrtle)		1	1
Olea europaea (wild olive)	6	4	10
Pistacia lentiscus (mastic tree)	469	5373	5842
Poaceae type *Festuca arundinacea*	19	128	147
Quercus sp., cupule (acorn)	2	7	9
Quercus sp., cotyledon (acorn)	1		1
Rosaceae, fruit fragment		2	2
Rosaceae, seed		4	4
cf. *Ruscus* sp.	4	2	6
Solanaceae		1	1
Stipa tenacissima, rhizome (esparto grass)	61	765	826
Taxus baccata (yew)	1	1	2
Withania sp.	2	1	3
Weeds			
Aizoon hispanicum		2	2
cf.*Asperula/Galium* sp.		1	1
Asteraceae		10	10
Centaurea sp.		1	1
Chenopodium cf. *album*		21	21
Chenopodium murale		54	54
Cleome sp.		2	2
Emex spinosa		1	1
Fumaria sp.		1	1
Galium sp.		6	6
Geraniaceae		8	8
Lamiaceae		5	5
Malvaceae		11	11
Phalaris sp.		1	1
Plantago sp.		14	14
Polygonum sp.		1	1
Portulaca oleracea		2	2
Scorpiurus muricatus		2	2
Small seeded legume	8	17	25
Indeterminated fruit		4	4
Indeterminated fruit fragment		1	1
Indeterminated seed	3	106	109
Indeterminated fragment	86	450	536
Total	742	7260	8002

Discussion

The palynological and wood charcoal sequences from Ifri Oudadane provide valuable data to reconstruct the environmental history of northeastern Morocco during the Epipalaeolithic–early Neolithic transition, the period when cultural landscapes start to develop in the region. Both sets of data offer different results. There is a group of trees and shrubs present in the pollen record which are completely absent in the wood charcoal from the site in spite of the high number of fragments analysed: *Abies, Cedrus,* *Ceratonia siliqua, Populus, Ilex, Tamarix, Taxus, Cistus, Rhamnus/Phillyrea* … This, rather than being a drawback, offers an excellent opportunity to explore natural dynamics and human impact. In the case of archaeological charcoal, how well it reflects paleoenvironment is a subject that has been long discussed (e.g. Asouti and Austin, 2005; Badal et al., 1994; Chabal, 1997; Heinz, 1990; Shackleton and Prins, 1992; Smart and Hoffman, 1988; Théry-Parisot, 2002; Thompson, 1994) with different schools of thought according to the emphasis placed on ecological or ethnobotanical interpretation. Accoding to Chabal (1997) charcoal can be a function of past vegetation if scattered charcoal from domestic use which represents a long period of activity is studied (for a recent synthesis see Théry-Parisot et al., 2010). Other archaeobotanists refuse to believe that charcoal can be interpreted strictly in this way, since fuelwood supply may vary according to human selection, fuel properties and changes in catchment areas (e.g. Shackleton and Prins, 1992; Smart and Hoffman, 1988; Thompson, 1994). The presence/absence of taxa in our samples may be conditioned by questions such as taphonomy, wood availability, the properties and uses of the different woods as fuels and also for other purposes – crafts, constructions, nuts or fodder – depositional habits, and cultural choices (Zapata, 2012: 178–180). Understanding that the interpretation of archaeological charcoal is a complex issue, the combination of different proxies strengthens the conclusions on the reconstruction of vegetation dynamics, human choices and human impact.

According to present data, between c. 11.0 and 7.6 ka cal. BP (Epipalaeolithic) the littoral zone of thermomediterranean Morocco was characterized by a relatively dense arboreal cover of evergreen sclerophyllous oaks (mainly *Quercus coccifera*), arar tree (*Tetraclinis articulata*) and/or phoenicean juniper (*Juniperus phoenicea*), carob tree (*Ceratonia siliqua*), and a well-preserved riparian forest (alder, ash, poplar and willow) in the local wadi-river environments. The mesomediterranean and higher vegetation belts may have been abundant in holm oaks (*Quercus ilex*) and Aleppo pines (*Pinus halepensis*), and locally cork oaks (*Quercus suber*) in wetter areas and deeper soils; whereas fir (*Abies pinsapo*) and cedar (*Cedrus atlantica*) forests developed in Rif mountains (Benabid, 2000; Benabid and Fennane, 1994). Climate at this time may have been warm and humid, as evidenced by the importance of riparian forest and the xerothermophilous macchia composed mainly by wild olive (*Olea europaea*) and mastic (*Pistacia lentiscus*). In this cultural phase, the landscape appears scarcely altered by human activities: the values of anthropogenic pollen indicators and coprophilous fungi are not significant. Archaeological charcoal on the site is a good proof of human exploitation of both, the riparian forest and the xerothermophilous macchia during this period. Wild olive (*Olea europaea*) and mastic (*Pistacia lentiscus*), in very similar proportions, constitute the bulk of the woods burnt at the site by hunter-gatherers (53% all together). *Alnus* and *Salix*, linked to water courses, sum to 33% of the fuel exploited during the Epipalaeolithic. Other plant macroremains (fruits and seeds) collected give significant information on human gathering of plant foods: dwarf palm (*Chamaerops humilis*), rose hips (Rosaceae), juniper fruits (*Juniperus phoenicea*), yew arils (*Taxus baccata*), wild pulses (*Lathyrus*/ *Vicia* sp.), acorns (*Quercus* sp.), mastic tree seeds (*Pistacia lentiscus*) and wild olives (*Olea europaea*) have been retrieved.

Between c. 7.6 and 6.6 ka cal. BP (Early Neolithic A and B), wild olive and mastic continue to be abundant as well as other elements of the xerothermophilous macchia and the riparian forest, reflecting a humid and warm climate. These data agree with the anthracological analysis carried out in the Djamila profile at the Lower Moulouya river (Linstädter and Zielhofer, 2010; Zielhofer et al., 2010), that shows the dominance of *Olea* and *Pistacia* records between c. 7.4 and 6.6 cal. BP. These findings correspond to several other paleoecological studies from adjacent regions in the Western Mediterranean, which show a maximum in humidity at that time (e.g. Carrión et al., 2001, 2003, 2004, 2010). As a general trend during the Early Neolithic (A to C) there is a progressive decline of arboreal percentages with respect to the Epipalaeolithic, mainly because of the loss of elements of the local forest such as kermes/holm oak (*Quercus ilex-coccifera* type), alder (*Alnus*), ash (*Fraxinus*), poplar (*Populus*) and willow (*Salix*). This seems to be related to a combination of two different processes: (1) the beginning of the production economy, and (2) the progressive aridification of the climate. Regarding the first process, the Early Neolithic A corresponds to the beginning of farming c. 7.6 ka cal. BP and is accompanied by the occurrence of anthropic indicators and ruderal taxa, such as *Aster*, Boraginaceae, Cardueae, Cichorioideae, *Centaurea nigra, Malva sylvestris, Portulaca oleracea, Solanum nigrum* and *Fumaria* (Behre, 1981; López-Sáez et al., 2003), typical taxa from cereal fields, fallow lands and roads, degraded scrub and watercourses in northern Morocco (Molero and Montserrat, 2006; Valdés et al., 2002). This is consistent with other archaeobotanical studies (Ballouche and Marinval, 2003; López-Sáez and López-Merino, 2008; López-Sáez et al., 2011) that demonstrate the adoption of agriculture in southern Iberia and northern Morocco during the second half of the 8th millenium cal. BP. The carpological information in Ifri Oudadane shows that during the early Neolithic a significant array of cereals and legumes are being used at the site: barley (*Hordeum vulgare*), hulled wheat (*Triticum monococcum/Triticum dicoccum*), free-threshing wheat (*Triticum aestivum/Triticum durum*), hard wheat (*Triticum durum*), pea (*Pisum sativum*) and lentil (*Lens culinaris*). On the contrary to what might be expected, the gathering of wild plants continues and even seems to increase during the Neolithic. Besides agriculture, forest decline during the three phases of the early Neolithic could be also related to grazing activities. Throughout the early Neolithic pollen spectra have indicators of pastoral pressure such as the coprophilous (dung-living) fungi *Cercophora*, *Sordaria*, *Sporormiella* and *Podospora* (López-Sáez and López-Merino, 2007; López-Sáez et al., 1998; van Geel, 1978; van Geel et al., 2003) or some pollen taxa (*Plantago lanceolata, P. major/media, Polygonum aviculare*, Chenopodiaceae) (López-Sáez et al., 2003), that suggests the presence of local animal husbandry (López-Sáez and López-Merino, 2007). The use of fuel by humans in Ifri Oudadane during the early Neolithic shows an increase in the use of *Pistacia* that might also be linked to pastoral activities. Ethnographic work carried out by us in the Moroccan Rif shows that trees such as *Pistacia* and *Fraxinus* are highly valued animal foods. The collection of tree fodder for domestic animals is a common activity with a twofold result since it provides food for the animals and remnant branches can also be used as fuel (Zapata et al., 2003). Thus, the use of the cave for pastoral activities might condition the composition of plant macroremain assemblages.

During the Early Neolithic C, the second process – climatic change – becomes clear, in this case related to an aridification indicated by the disappearance of riparian taxa (alder, ash, willow), higher *Artemisia* percentages (Barathon et al., 2000) and the development of a xerothermophilous macchia mainly composed by *Pistacia lentiscus, Erica arborea* type, *Myrtus communis, Genista* type, *Lavandula stoechas, Smilax, Rhamnus alaternus* type, *Whitania, Ziziphus, Periploca, Phillyrea, Cistus* type, etc. Thus, the adoption of farming in northeastern Morocco seems to have occurred under the favourable conditions of the mesophytic optimum and progressed under the drying environmental conditions after 6.6 ka cal. BP (Carrión et al., 2010; Holmes, 2008; Wengler and Vernet, 1992). The disappearance of alder during ENC is attested in the site by both proxies – pollen and wood charcoal – and is extremely interesting. Black alder (*Alnus glutinosa*) is naturally widespread across Europe, from mid-Scandinavia to the Mediterranean countries, Caucasus, Western and

Central Asia, Siberia and Northern Africa (Kajba and Gracan, 2003; Prada and Arizpe, 2008). Alder prefers temperate to cool climates, although it is adapted to a wide range of temperatures and soils of varying nutrient status but its occurrence is closely linked to conditions of adequate water intake. Consequently, the range of the species is limited by aridity (annual rainfall below 500 mm) (Claessens et al., 2010). At the drier limits of this range (northern Africa), it finds refuge in the humid microclimates of valleys, for example in the Atlas Mountains (Benabid, 2000; Charco, 1999, 2001). *Alnus* can suffer from water deficits during dry and warm periods in summer, and if annual precipitation is not high, it can die. In natural conditions, its regeneration is dependent on soil disturbance (e.g. by flooding or forest harvesting) or changes in the forest cover caused by diseases or clearfelling (Gill, 1970). Suitable conditions for natural regeneration occur rarely in anthropogenic landscapes (Claessens, 2003). *Alnus* survived in the study area of northern Morocco until c. 6.7 ka cal. BP and is well represented in the Ifri Oudadane sequence from the Epipalaeolithic to the Early Neolithic B, but it disappears in the Early Neolithic C when arid conditions take place. The end of initial soil formations in the alluvial deposits of the Lower Moulouya valley (Linstädter et al., 2012) and the Oued Kert valley (Barathon et al., 2000) testify to these environmental shifts, that otherwise might have favoured the development of tamarisk (*Tamarix*), probably *T. africana* or *T. gallica*, more adapted to intercept deep water-tables and exploit natural water resources in fresh or brakish places in the region (Benabid and Fennane, 1994; Ennabili and Gharnit, 2003). Currently, alder is not present in the study area (Kajba and Gracan, 2003) and, besides environmental conditions, it cannot be dismissed that its disappearance might also be related to increasing anthropogenic pressure from the early Neolithic. Summarizing, the Early Neolithic C is characterized by a more pronounced degradation of forest into shrubland communities (macchia), while coprophilous fungi and cereal pollen decrease, possibly indicating a reduced pressure from animal grazing and agriculture. The percentage of *Cerealia* type was low (<3% in two samples) and should be considered evidence of agriculture in the proximity of the study site, but not necessarily at the site ifself (López-Sáez and López-Merino, 2005).

Conclusions

The Ifri Oudadane sequence offers through an interdisciplinary approach new palaeoenvironmental data from the Mediterranean Maghreb for the period c. 11 ka cal. BP to 5.7 ka cal. BP, a critical chronology to assess the origin of cultural landscapes and ecosystems in the region. According to palaeobotanical data, significant transformations take place related both to anthropic and climatic reasons. The following conclusions can be put forward:

(1) *Vegetation dynamics and landscape reconstruction.* Intense landscape transformation takes place with the transition to the early Neolithic (c. 7.6 ka cal. BP). Last hunter-gatherers occupied a region with a quite dense woodland cover of evergreen sclerophyllous oaks (mainly kermes oak, *Quercus coccifera*), arar tree (*Tetraclinis articulata*) and/or phoenicean juniper (*Juniperus phoenicea*), carob tree (*Ceratonia siliqua*) and well-developed riparian forest (*Alnus, Fraxinus, Populus, Salix*). During the early Neolithic (c. 7.6–6.3 ka cal. BP) there is a progressive decline of arboreal components mainly because of the loss of elements of the local forest such as kermes/holm oak (*Quercus ilex-coccifera* type), alder (*Alnus*), ash (*Fraxinus*), poplar (*Populus*) and willow (*Salix*). Particularly significant is the virtual disappearance of riparian taxa (*Alnus, Fraxinus, Salix*) during the Early Neolithic C both in the charcoal and pollen records which strongly suggests a climatic aridification.

(2) *Subsistence and human use of plant resources*. Epipalaeolithic hunter-gatherers exploit plant resources for fuel (*Olea, Pistacia* and *Salix* in particular) and gather wild plants (*Chamaerops humilis*, Rosaceae, *Juniperus phoenicea, Taxus baccata* wild *Lathyrus/Vicia* sp., *Quercus* sp., *Pistacia lentiscus* and *Olea europaea*). During the Neolithic period the exploitation of similar fuels continues on the site (*Pistacia* and *Juniperus* in particular) but it may have been conditioned by their use as tree fodder. Plant macroremains during the early Neolithic show the continuation and intensification of wild plant gathering but farming is also documented with crops such as barley, different types of wheat, pea and lentil.

(3) *Human impact*. During the Epipalaeolithic, between c. 11.0 and 7.6 ka cal. BP, although human action and plant exploitation is taking place, landscape appears scarcely altered. However, the Neolithic (c. 7.6–6.3 ka cal. BP) results in significant human impact from the very beginning. Crop macroremains are present and pollen indicates cultivation not far from the site. Coprophilous fungi give direct evidence for the presence of ovicaprides. The decline of trees and shrubs by simultaneous increase of grasses indirectly prove grazing activities and herding pressure. This herding pressure reduces during the ENC at c. 6.6 ka cal. BP but the progressive decline of arboreal components continues together with the extension of shrubs.

(4) *Correlation between cultural and environmental changes*. There is a correlation between cultural and environmental changes. The occupation of the shelter starts with improved conditions at the beginning of the Holocene c. 11.0 ka cal. BP with a warm and humid climate. The most visible environmental changes of the sequence take place at the beginning of the Neolithic c. 7.6 ka cal. BP because of anthropogenic impact by the establishment of a mixed economy which includes diverse farming practices. In northeastern Morocco the adoption of farming seems to have occurred under the favourable conditions of the mesophytic optimum. However, the upheaval in vegetation cover during the Neolithic transition may have also been accompanied by the onset of environmental deterioration. The less marked change to the late early-Neolithic (ENC) announces the following phase of environmental disfavour and is visible by a decrease of anthropic taxa together with botanical indicators for aridity. The synchronous increase of shrubs like *Tamarix* and grasses such as *Artemisia* indicate drier conditions and attest that the reduction of human action may have been triggered by climatic deterioration. Trees could not recover and vegetation developed into shrub communities of xerothermophilous macchia. In this case climate had a much higher impact and most probably resulted in the virtual abandonment of the site and its surroundings during the first half of the 6th millennium cal. BP.

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