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Environmental changes in Lebanon during the Holocene: Man vs. climate impacts

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ABSTRACT

Pollen and archaeological studies were undertaken in the Southern Bekaa Valley (Lebanon, Mediterranean region). Two Holocene records retrieved in the Aammiq and Chamsine/Anjar wetlands, respectively located at the foothills of Mount Lebanon and Anti-Lebanon Mountain, in the Southern Bekaa Valley, were analyzed to highlight climatic vs. anthropogenic influence on landscape patterns. Our data records support hypothesis on climatically driven modification during the Late Glacial Age and the early Holocene. Human disturbances in the study area are only depicted after c. 8 ky cal. BP, with different patterns in eastern and western parts of the Southern Bekaa Valley. These modifications are in line with major landscape changes in the Eastern Mediterranean region. Since c. 8 ky cal. BP, major deforestation events on Mount Lebanon are recorded in the Aammiq area depicting human interference, while in Chamsine/Anjar, no sign of such activities can be interpolated since strong deciduous oak development is recorded. Archaeological records from the same region confirm human impact on the forest during the Neolithic period. Numerous bifacial flint tools, such as axes, adzes, and chisels, manufactured in the prehistoric workshops of the Southern Bekaa Valley, attest to the beginning of the deforestation during this period. From c. 3.5 to c. 2 ky cal. BP, deforestation seems reduced on Mount Lebanon while in the Chamsine/Anjar area oak forest expansion is still recorded. During the same period, grazing activities were performed in the Bekaa Valley.
Between c. 2 and c. 1 ky cal. BP, and on both sites, deforestation and grazing practices are inferred from pollen records. No cultivated plants are recorded in this region. In this view, these Holocene data illustrate important differences in patterns of human activity in comparison with other areas located in the Eastern Mediterranean, where cultivated olive trees and forests decline are well identified. From c. 1 ky cal. BP into the modern period, increasing human perturbations affected the pollen record on both sites.

1. Introduction

The human impact on the environment is an object of interest in our days. The CO_2 increase in the atmosphere and its effects as greenhouse gas are studied from different aspects aiming to understand how and when these changes occurred. The concentration of CO_2 in the atmosphere has increased drastically and steadily since the pre-industrial era (Crutzen and Stoermer, 2000), a phenomenon which inevitably leads to global warming and strong climate variability (IPCC, 2007). But what if human beings had an impact on climate much earlier than the last two centuries? Indermühle et al. (1999) shows an increase of atmospheric CO_2 concentration since c. 8 ky cal. BP and suggests that terrestrial biomass and sea surface temperature were largely responsible for the observed variations. Few years later, Ruddiman (2003) developed a new hypothesis, which affirms that "pre-industrial forest clearance in Eurasia since c. 8 ky cal. BP explains the rise in the concentration of atmospheric CO_2 between c. 8 ky cal. BP and c. 1.8 ky AD." In fact, cultivated plants are recorded in the Fertile Crescent since the beginning of the Neolithic[1] on several archaeological sites (Colledge et al., 2004; Twiss, 2007). During the PPNB,[2] plant cultivations are identifiable in several parts of the Fertile Crescent (Appendix 1, electronic version only). After the PPNB, domesticated cereals and animals are encountered in several sites from the Eastern Mediterranean. These archaeological reconstructions are reinforced by palaeobotanical studies where the main

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[1] c. 11.5–c. 8.5 ky cal. BP (after Aurenche et al., 1981).
[2] Pre-Pottery Neolithic B – period initially defined by Kenyon (1956, 1960) on the stratigraphic subdivisions at Jericho (Israel), between c. 10.7 and c. 9 ky cal. BP (after Aurenche et al., 1981).

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cultivated plants and deforestation were recorded (Appendix 1). In the Fertile Crescent, pollen records from Israel (Baruch, 1990; Schwab et al., 2004) show olive cultures and oak deforestation since c. 6 ky cal. BP. In Syria (Niklewski and van Zeist, 1970; Yasuda et al., 2000), olive cultures are also recorded but problems of dating prevent the arriving to any conclusions about the beginning of such human events (Meadows, 2005).

Palaeobotanical studies dealing with the impact of man on palaeoenvironments were carried out throughout the Fertile Crescent (Yasuda et al., 2000; Schwab et al., 2004; Neumann et al., 2007). However, there is a gap in our knowledge about palaeoenvironments of the Holocene in Lebanon, a critical region for understanding the expansion of agricultural societies in the Near East. In an attempt to provide additional information on past vegetation dynamics over the Eastern Mediterranean region and assess the importance of human activity regarding landscape changes, this paper presents a comparative approach between palaeobotanical data (two Holocene pollen records) and archaeological data (eight Neolithic sites) in the Southern Bekaa Valley.

2. Study area

The Aammiq and Chamsine/Anjar wetlands are situated in the Southern Bekaa Valley between Mount Lebanon and Anti-Lebanon Mountain (Fig. 1).

The Bekaa is considered one of the most important agricultural zones in Lebanon, producing 57% of the vegetables, 37% of the fruit trees, and 62% of the industrial cultures of the country. The beetroot is one of the most important industrial crops produced in the Bekaa, followed by potato, cereals, and grains. Grapes are also considered an important production of the Bekaa Valley with almost 0.067 km^2 of vineyards (Ministère de l'Agriculture/FAO, 2005).

Pastoralism in Lebanon, and especially in the Bekaa, is still considered a major source of activity as 67% of total livestock in Lebanon are present in the Bekaa (31% of bovine and 36% of ovine) (Ministère de l'Agriculture/FAO, 2005).

The vegetation of Lebanon is described by Abi-Saleh (1978). On the eastern slope of Mount Lebanon around the Aammiq wetland, three vegetation levels are present. Between 800 and 1000 m (Eumediterranean level), Mount Lebanon is covered mainly by *Quercus calliprinos* formation with scattered trees and degraded forests, along with other trees and shrubs such as *Sarcopoterium spinosum*. Between 1000 and 1600 m (Supramediterranean level), mixed series of *Quercus calliprinos* and *Quercus infectoria* forests are observed. Above 1600 m (Mountain Mediterranean level), a *Cedrus libani* forest develops only on the western slopes of Mount Lebanon. The cedar forest includes some scattered trees and shrubs such as *Berberis libanotica*, *Lonicera nummulariifolia*, and *Quercus brantii*.

The Aammiq wetland receives its water supply from the Riachi River (only during rainy season), precipitation, springs, snowmelt, and mainly drained water. The marsh (2.8 km^2) is bound by the Barouk Mountain and the Litani River. During the summer a part of the wetland dries out. The Chamsine/Anjar wetland receives its water supply from springs, precipitation, snowmelt, and also drained water coming from the Anti-Lebanon Mountain (El Hakim, 2005).

The Bekaa Valley records c. 850 mm of annual precipitation, a mean temperature for the coldest month of c. 2 °C, and a mean temperature for the warmest month of c. 33 °C (Ministry of Environment/Med Wet Coast Project, 2004).

The following archaeological sites: Majdel Anjar I, Dakwe I–II, Kamed el Loz I, Qar'oun I–II, Souwan, Kefraya, Wadi Msîl el Hadd and Beïdar Chamoût (Haïdar-Boustani, 2004a,b) are situated in the Southern Bekaa Valley (Fig. 1).

3. Material and methods

3.1. Palynological data

Two cores were extracted, using a Russian corer, in the Aammiq wetland (33°46′N, 35°46′E, 865 m, 5.40 m long) and in the Chamsine/Anjar wetland (33°44′N, 35°57′E, 856 m, 3.10 m long) (Fig. 1). Nine AMS ^{14}C dates were made on sediments (Table 1, nomenclature follows Troels-Smith, 1955). Four AMS ^{14}C dates have been obtained on the Aammiq core and five AMS ^{14}C dates on the Chamsine/Anjar core (Table 1) (Fig. 2). Earlier studies have shown potential problems related to the hard water effect and contamination when dating sediments (Olsson, 1973, 1983). Hard water effect usually provides older dates when dating sediments (Olsson, 1983). Consequently, the absence of mismatching between our palynological results in Lebanon and others regional palynological studies in Israel and Syria permits to dismiss problems of date aging. Moreover, the age/depth models performed using a linear interpolation between the radiocarbon dates (Fig. 2) seem to be reliable. Carbon dates have been calibrated with the CALIB 5.0 program (Stuiver and Reimer, 1993) with the calibration curve Intcal04 (Reimer et al., 2004). The confidence interval between the minimum and maximum calibrated dates at 2σ (Table 1) corresponds to the time interval shown in Fig. 2.

Pollen analyses with a ~200-year intervals were carried out (Figs. 3 and 4) at the Université Montpellier 2, CNRS, Institut des Sciences de l'Evolution (ISEM, France).

The extraction of pollen grains followed standard methods (Faegri and Iversen, 1989) including cold HCl digestion to remove carbonates, hot KOH to remove soluble humic acids and cold HF to remove silicates. Finally, fluo-silicates were eliminated using cold HCl. The residue is mixed with a known volume of glycerin in order to mount the slides for the pollen count under the optical microscope using a 60 magnification for pollen recognition. More than 300 pollen grains per sample were counted excluding aquatics, swamp, and damaged pollen grains – with the exception of particularly poor samples. As they dominate the local landscape, all aquatic plants and Cyperaceae were excluded from the total pollen sum.

Two types of oaks were identified: *Quercus cerris*-type which includes pollen grains of *Q. brantii*, *Q. cedrorum*, *Q. cerris*, *Q. infectoria*, *Q. libani* and *Q. pinnatifida* (deciduous oaks); and *Quercus* sp. which includes pollen grains of *Quercus* not identifiable. As *Q. calliprinos* is the only Lebanese evergreen oak, evergreen oak pollen grains correspond to *Q. calliprinos* species (Figs. 3 and 4).

All taxa identified during the pollen counting are represented in the pollen diagrams (Fig. 3 and 4). However, taxa with less than 1% were bulked under the categories "other trees", "other shrubs", and "other herbs".

In Fig. 5, the curve of anthropogenic indicators sums the percentages of *Olea*, *Centaurea nigra*-type, *Plantago lanceolata*-type, *Cerealia*-type, *Humulus/Cannabis*, *Polygonum aviculare*-type, *Sanguisorba minor*-type, *Sesamum* and Urticaceae. Those taxa have been chosen on the basis of Bottema and Woldring (1990) and Fall et al. (2002) and are typical anthropogenic pollen indicators in the Mediterranean region.

Contaminated sediments during the coring (melting of sediments) between 360 and 380 cm on the Aammiq core and between 250 and 280 cm on the Chamsine/Anjar core were removed from pollen records (Figs. 3 and 4).

During the analysis, the evaluation of sediment material components on each slide was attempted following Troels-Smith (1955). On the Aammiq core, magnetic susceptibility was measured at a 5 cm interval (Fig. 3) using a type Bartington M.S.2 system in the laboratory of Geosciences Montpellier, CNRS, UMR 5243

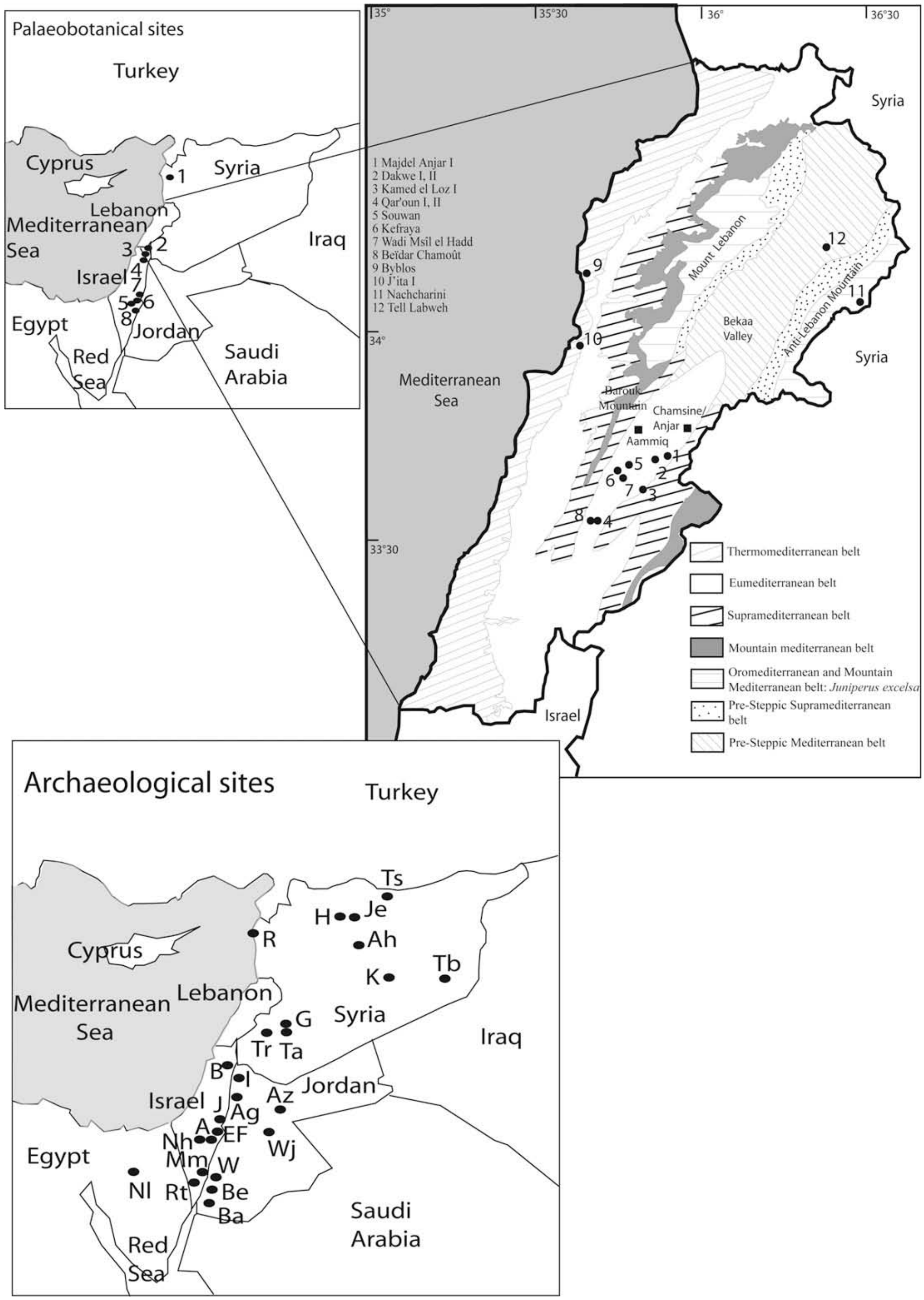

Fig. 1. Geographical location of sites discussed in the text. Palaeobotanical sites – 1: Ghab Valley, 2: Birkat Ram, 3: Hula Basin, 4: Kinneret Basin, 5: Ein Gedi, 6: DS 7–1 SC (Dead Sea), 7: Ein Feshkha, 8: Ze'elim. Archaeological sites – Egypt: Nl: Nahal Lavan 109; Israel: A: Abou Gosh, B: Beisamoun, EF: Ein Feshkha, J: Jericho, Mm: Mesad Mazzal, Nh: Nahal Hemar, Rt: Ramat Tamar; Jordan: Ag: Ain Ghazal, Az: Azraq, Ba: Basta, Be: Beidha, I: Iraq ed-Dubb, W: Wadi Fidan A, Wj: Wadi el Jilat 7; Syria: Ah: Abu Hureyra, G: Ghoraïfé, H: Halula, Je: Jerf el Ahmar, K: El Kown II, R: Ras Shamra, Ta: Tell Aswad I and II, Tb: Tell Bouqras, Ts: Tell Sabi Abyad II, Tr: Tell Ramad.

(France). The work of Dearing (1999) provides different values of magnetic susceptibility for different types of sediments and helps in interpreting the results of the analysis.

In order to understand which factor determines the variations of the taxa percentages in the pollen sequences, a correspondence analysis (Benzécri, 1973) was performed on the data from the Aammiq and Chamsine/Anjar wetlands using the R statistical software version 2.6.1 (Fig. 6a and c). The correspondence analysis was applied to all the taxa except aquatics and Cyperaceae because they dominate the local landscape. The first analysis was carried out on 31 taxa and 95 samples for Aammiq and on 32 taxa and 69 samples for Chamsine/Anjar.

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Table 1
Radiocarbon dates obtained for the Aammiq and Chamsine/Anjar records.

Core	Mid-point (cm)	Thickness (cm)	Laboratory number	AMS ^{14}C age (^{14}C years BP)	Standard deviation	Minimum calibrated age	Mean calibrated age	Maximum calibrated age	Dated material
AM1	123.5	1	Poz-14709	3575	35	3730	3850	3975	Argilla steatodes
AM1	253.5	1	Poz-14710	6780	50	7525	7610	7695	Turfa lignosa
AM1	341	4	Gif-12104	9110	90	9945	10,250	10,555	Turfa lignosa
AM1	428.5	1	Poz-14711	10,360	60	11,990	12,285	12,580	Limus detrituosus
CHA2	67.5	1	Poz-18720	960	30	795	860	930	Argilla steatodes
CHA2	109.5	2	Poz-14712	3105	35	3240	3320	3395	Turfa lignosa
CHA2	172	2	Poz-18722	6110	40	6890	7025	7160	Argilla steatodes
CHA2	239.5	1.5	Poz-14713	9300	60	10,280	10,445	10,610	Argilla steatodes
CHA2	248	2	Poz-18723	9770	50	11,105	11,180	11,260	Argilla steatodes

AM1 = Aammiq; CHA2 = Chamsine/Anjar; Poz = Poznan Radiocarbon Laboratory (Poland); Gif = Laboratoire des Sciences du Climat et de l'Environnement (Gif sur Yvette, Paris).

3.2. Archaeological data

The studied archaeological material (Haïdar-Boustani, 2004a,b) has been collected on the surface. We focused on the flint industries in order to, first, recognize the manufacturing process of the Neolithic bifacial tools such as axes, adzes, and chisels (Appendix 2, drawing Maya Haïdar-Boustani electronic version only), which are abundant in the workshops of the Southern Bekaa Valley (Majdel Anjar I, Dakwe I–II, Kamed el Loz I, Qar'oun I–II, Souwan, Kefraya, Wadi Msîl el Hadd and Beïdar Chamoût) (Fig. 1) and, second, fit this phenomenon in a chronological and cultural framework. No absolute dating is available for the archaeological data, but relative dating is possible in comparing the flint workshops from the Bekaa Valley. In the actual state of the research in Lebanon (Haïdar-Boustani, 2004c), the only excavated Neolithic site where the bifacial flint tools have been recovered in stratified deposits is Byblos (Cauvin, 1968), which is not enough to establish the comparisons and get a date for the sites concerned here. But if we take into account the history of the bifacial tools in the Near East, especially the archaeological context and the similarity between the artifacts of the Southern Bekaa Valley and those of the Southern Levant, we can assume that the workshops of this first area have been frequented during the Late PPNB (c. 9.6–c. 9 ky cal. BP, c. 7.6–c. 7 ky cal. BC) and/or the Pottery Neolithic (c. 9–c. 7 ky cal. BP, c. 7–c. 5 ky cal. BC). It is difficult to be more precise as long as none of the workshops have been excavated.

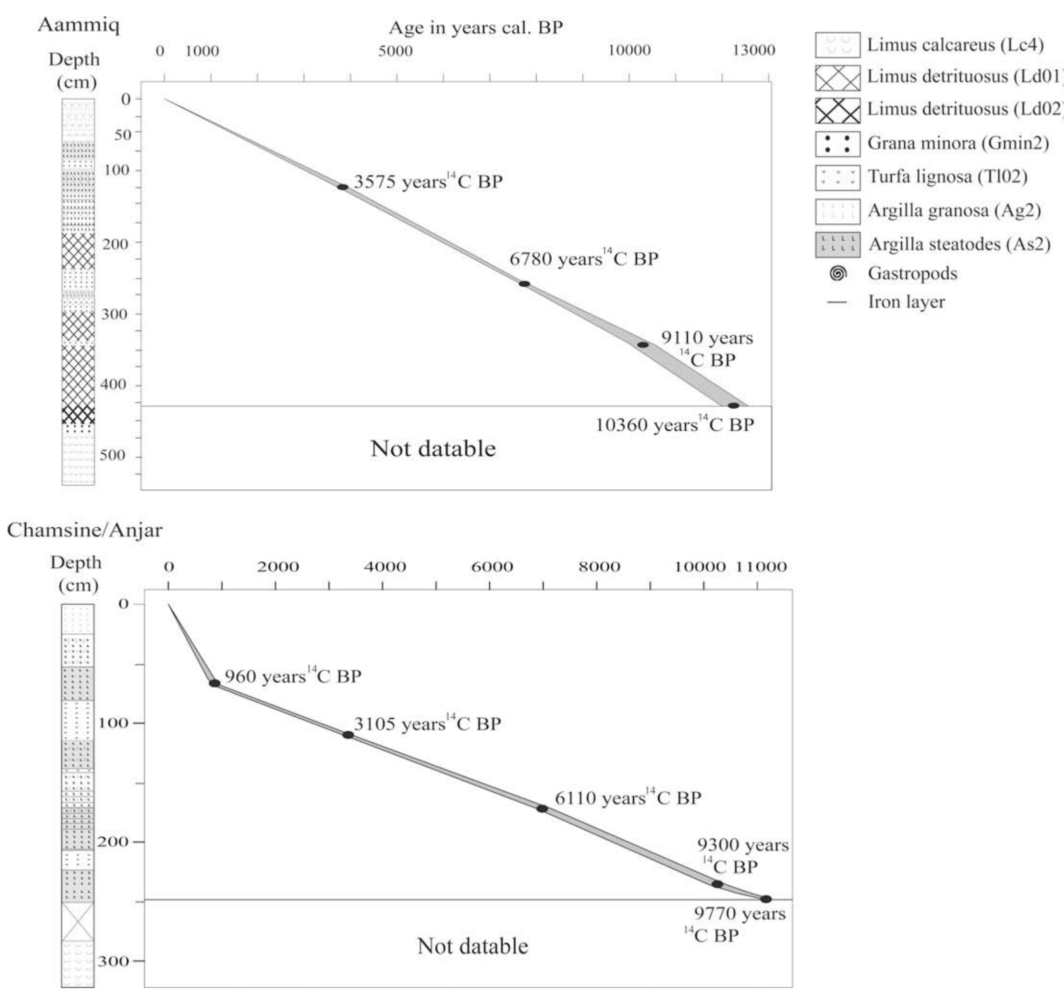

Fig. 2. Age/depth model based on calibrated ^{14}C dates.

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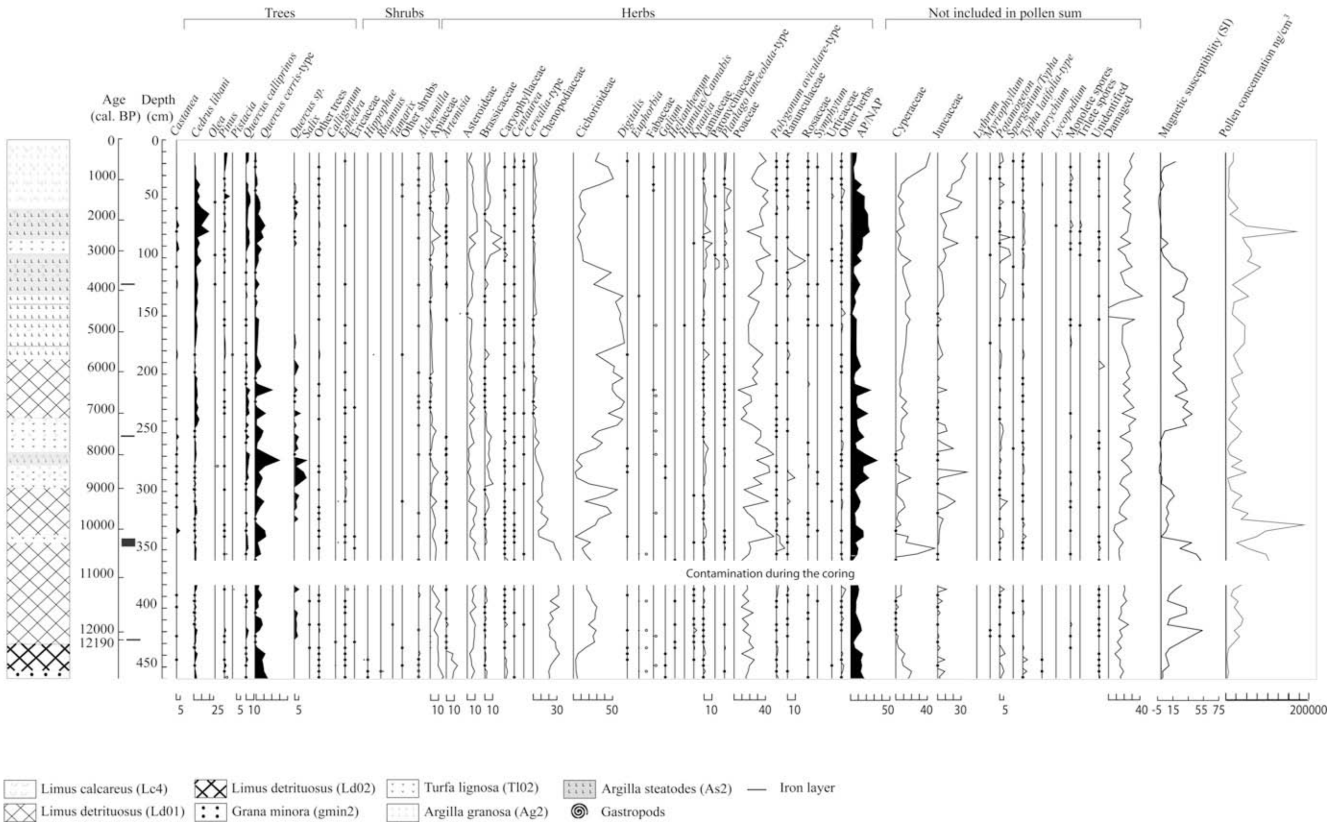

Fig. 3. Pollen diagram from the Aammiq core.

4. Results

The Aammiq pollen sequence (Fig. 3) presents a dated record which spans from the Younger Dryas to the present day. The Chamsine/Anjar pollen diagram (Fig. 4) is dated from c. 11 ky cal. BP to the present day. Before c. 11 ky cal. BP, major percentages of Chenopodiaceae are recorded in both diagrams. Cichorioideae dominate the pollen records between c. 11 and c. 9 ky cal. BP, and deciduous oak dominates from c. 9 to c. 8 ky cal. BP.

After c. 8 ky cal. BP, discrepancies between the two records are noticed. The Chamsine/Anjar record shows high percentages of deciduous oak, while the Aammiq pollen record presents low percentages of trees with high percentages of Cichorioideae synchronous with high values of magnetic susceptibility. The pollen records of the two sites are again comparable after c. 3 ky cal. BP where AP percentages dominate.

Anthropogenic indicators are low in the two pollen diagrams (Fig. 5). They are well identified in the two pollen records only between c. 2 and c. 1 ky cal. BP synchronously with the decrease of tree pollen percentages. No major indicators for plant cultures are recorded in the two pollen diagrams. After c. 1 ky cal. BP, Cichorioideae dominate both pollen records till the top of the core.

4.1. Statistical analysis

The first two axes of the correspondence analysis performed on the Aammiq data account for 37% of the total inertia, while for the Chamsine/Anjar data they represent 65% of the total inertia (Fig. 6). The most important variables, in terms of contribution to the axis variances, are listed in Appendix 3 (electronic version only) for both Aammiq and Chamsine/Anjar data. The correspondence analysis (Fig. 6) shows similar results for both analyses on Aammiq and Chamsine/Anjar pollen data (Fig. 6a and c). The Cichorioideae (Cic) scores are opposed to those of the majority of the other taxa along the first axis for both analyses. Cichorioideae are not characteristic of a particular environment, and this opposition is probably not related to ecological factors.

In both analyses, Chenopodiaceae taxa have the major contribution to the second-axis variance (Appendix 3, electronic version only). The second axis contrasts taxa from open vegetation and forest ecosystems. Open vegetation is represented by pollen grains of Chenopodiaceae, *Ephedra* and Ericaceae. These taxa are characteristic of dry steppe vegetation occurring during periods such as the Younger Dryas (Rossignol-Strick, 1995).

Forest ecosystems are characterized in both pollen records by major percentages of trees as oaks, cedars, and pines (Fig. 6) and of herbaceous taxa growing during warm and humid periods. In those pollen records, the herbaceous taxa are in majority Brassicaceae, Lamiaceae, Poaceae, and Ranunculaceae.

As a consequence, the second axis also shows the opposition between periods of arid and cold climate (Younger Dryas period) and humid and warm periods (Bølling/Allerød, Holocene periods).

Fig. 6b and d aims at presenting differences between scores of the two axes. Fig. 6b shows that scores of the first axis and scores of the second axis are anti-correlated from c. 10 ky to 0 cal. BP. Before c. 10 ky cal. BP, scores of both axes decrease synchronously. Fig. 6d shows that scores of the two axes are anti-correlated only from the beginning of the core to c. 10 ky cal. BP and from c. 1 ky cal. BP to the end of the core.

5. Discussion

The multivariate analysis performed on Aammiq and Chamsine/Anjar pollen data allows for the assessment of variations in the percentages of taxa in the two pollen diagrams and suggests hypothesis regarding their causality. In both analyses, the first axis

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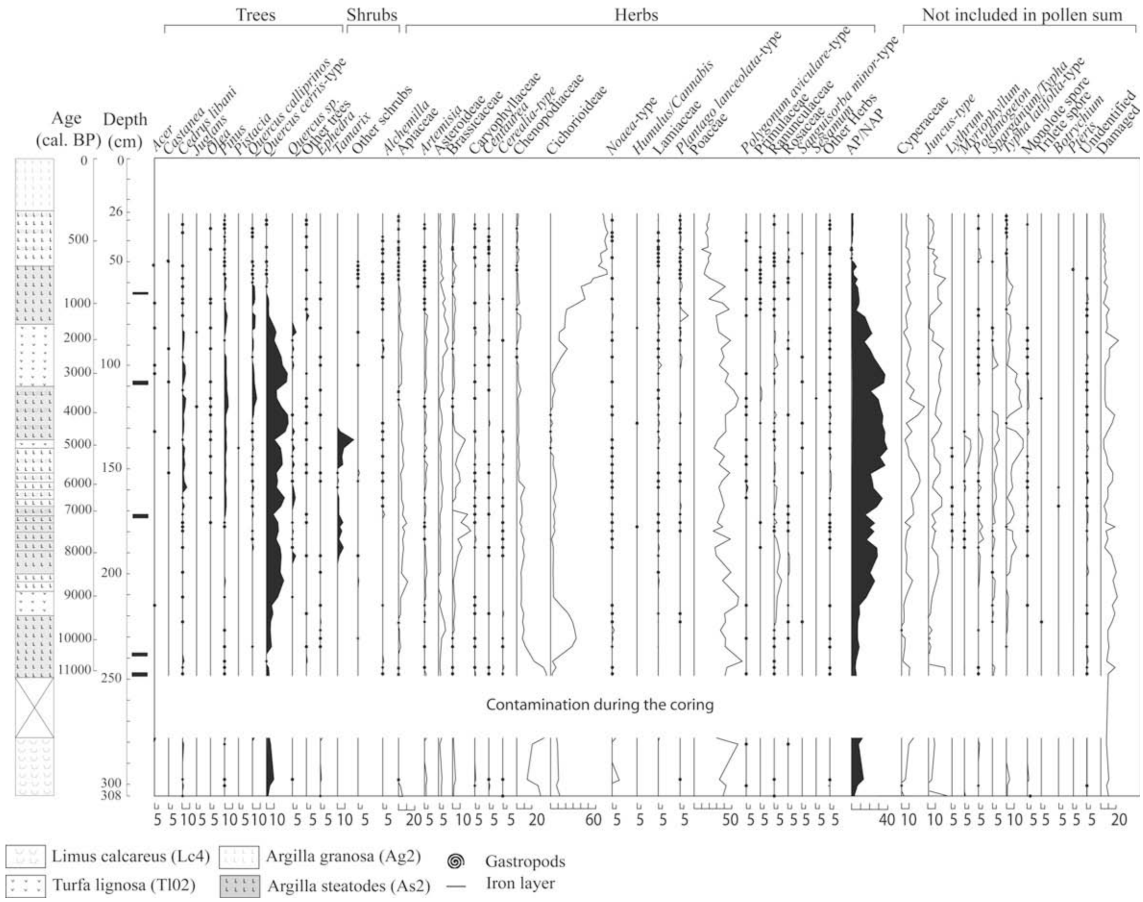

Fig. 4. Pollen diagram from the Chamsine/Anjar core.

(Fig. 6a and c) stresses the importance of Cichorioideae vs. other taxa on both Aammiq and Chamsine/Anjar diagrams. Bottema (1975) and Hajar et al. (2008) have shown that the dominance of Cichorioideae in pollen records is not necessarily meaningful of vegetation changes since they might be related to local perturbations such as soil erosion, local climate change, or irrigation. In both pollen records, the second axis (Fig. 6a and c) may be interpreted as relating the influence of global climate changes on the variations of the pollen percentages in the pollen records and consequently on the vegetation communities.

This suggests that pollen percentages in both diagrams are mainly affected by local perturbations but they also respond to global climatic changes.

However, comparison between scores of the first and the second axis (Fig. 6b and d) shows that Aammiq and Chamsine/Anjar pollen records cannot be identically interpreted.

An anti-correlation between the scores of the two first axes in Fig. 6b shows that the variation of the scores of the second axis is dependent on the variation of the scores of the first one (Guttman/arch effect, see for example: Kruskal and Wish, 1991; Brazill and Grofman, 2002). Consequently, the Aammiq pollen record seems importantly related to the variation of Cichorioideae percentages and consequently to sediment perturbations since c. 10 ky cal. BP. Furthermore, Chenopodiaceae and Poaceae contribute the most to the variance of the second axis (Appendix 3). Those taxa, as herbaceous taxa, are characteristic of the local environment around the marsh and show that the Aammiq pollen sequence seems to record, mainly, local vegetation changes in the marsh.

On the contrary, between c. 10 and c. 2 ky cal. BP in Fig. 6d, this anti-correlation is not observed, showing that a factor other than sediment perturbations influences the Chamsine/Anjar pollen record. The second axis is interpreted as relating the influence of global climate changes on the variations of pollen percentages as Chenopodiaceae and *Q. cerris*-type are the taxa which contributed the most to the variances of the second axis. Consequently, the Chamsine/Anjar pollen record seems to present regional vegetation changes.

During the Holocene, synchronous perturbations in the pollen record, marked by the increase of Cichorioideae percentages, are recorded in both diagrams (Fig. 5) between c. 10 and c. 9 ky cal. BP. More data are needed to understand precisely what caused such a pollen record during this period. In the Eastern Mediterranean region, deciduous oak forest development is recorded in the Ghab Valley in Syria (Yasuda et al., 2000) and in the Hula Basin in Israel (Baruch and Bottema, 1991) during this period. These findings do not concord with the pollen record from the Southern Bekaa Valley. Therefore, the changes in oak forests of the Levant during the Holocene seem to represent different patterns of human occupation in each region rather than large-scale climatic changes.

Between c. 8 and c. 3.5 ky cal. BP, as cores from Aammiq and Chamsine/Anjar are separated by 12 km, differences between the two pollen records from the Southern Bekaa Valley (Fig. 5) suggest that the local perturbations in the Aammiq wetland were probably caused not by climate change but rather by human activity. In fact, if a climate variation had occurred during this period in the Bekaa Valley, perturbations would have been observed in both pollen records. Moreover, the record from Chamsine/Anjar wetland is similar to those records in the Eastern Mediterranean region where the expansion of deciduous oak is shown (Robinson et al., 2006) and reinforces the idea that human activity certainly dominated

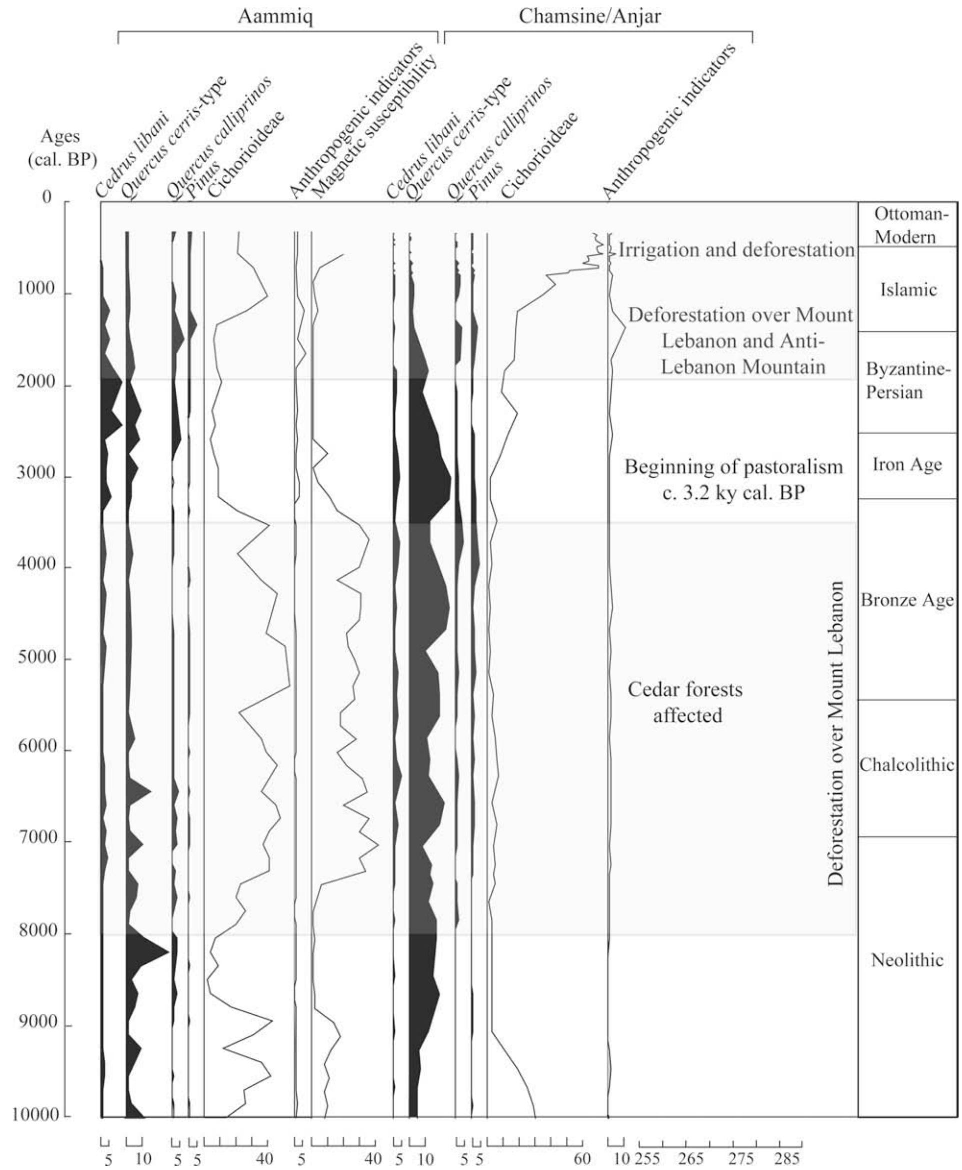

Fig. 5. Percentage pollen of trees and anthropogenic indicators from Aammiq and Chamsine/Anjar cores and magnetic susceptibility from Aammiq core.

local impact in the Aammiq wetland. Perturbation of the pollen record, marked by the increase of Cichorioideae, could have been caused by an irrigation of the marsh. However, unlike in the North Levant since the Neolithic period (Moore, 1980; Cauvin et al., 1998) and along the Jordan rift during the Bronze Age (Fall et al., 2002), no evidence of irrigation has been found in the Bekaa Valley (Haïdar-Boustani, 2004c).

Synchronously to the increase of Cichorioideae, the increase of magnetic particles (Fig. 5) in the Aammiq wetland may indicate an important erosion of the eastern slope of Barouk Mountain during this period. As no drought signs are recorded during the middle of the Holocene in the area (Robinson et al., 2006), and as no such perturbation of the Chamsine/Anjar pollen record is observed, this major erosion is certainly due to major human activity such as the deforestation of oak and/or cedar forests on Mount Lebanon.

The deforestation events supported by pollen analysis are also attested by the archaeological data, especially the abundant typical tools of the Neolithic such as axes, adzes, and chisels, which are manufactured in specialized sites: the workshops (Majdel Anjar I, Dakwe I–II, Kamed el Loz I, Qar'oun I–II, Souwan, Kefraya, Wadi Msîl el Hadd and Beïdar Chamoût) (Fig. 1). All the stages of the manufacturing process (rough-out, pre-form, and finished tool) are attested Regarding the finished tools, we have not only the typical tools of the Neolithic such as axes, adzes, and chisels, which are produced in all the workshops, but also a special morphology called ''orange slice''[3] occurring in some sites (Majdel Anjar I, Dakwe I–II, Qar'oun I–II, Kefraya, and Beïdar Chamoût). The increase of the bifacial flint tools, associated with wooden artifacts, has been identified mainly in the Southern Levant. This phenomenon was initiated in the Early PPNB with Nahal Lavan 109 (Barkai, 2001) and developed during the Late PPNB with Ramat Tamar, Mesad Mazzal (Taute, 1981, 1994), Abou Gosh, Beisamoun (Lechevallier, 1978), and many other sites, till the end of the Pottery Neolithic and even later (Barkai, 2005).

During the middle of the Bronze Age (c. 5.5 ky cal. BP), major deforestation of cedar forests in Mount Lebanon by the Egyptians, reported by Loffet (2004), is coherent with our data as the

[3] Translated from the French expression: ''quartier d'orange''. For more details see Hamal-Nandrin and Servais (1928), Cauvin and Cauvin (1968) and Haï-dar-Boustani (2004a,b).

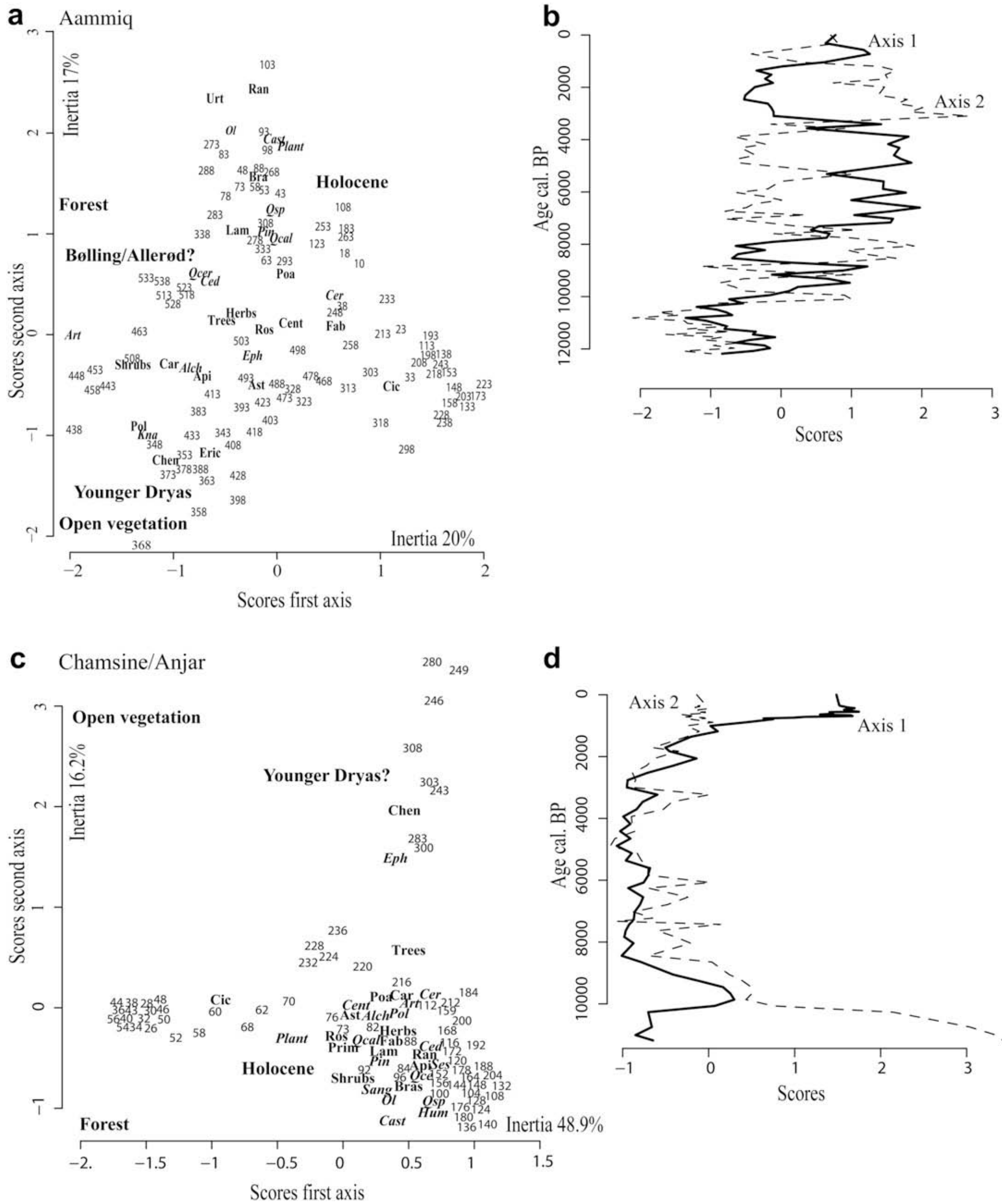

Fig. 6. (a, c) Correspondence analysis on Aammiq and Chamsine/Anjar data. (b, d) Scores of the two first axes of the correspondence analysis. *Alch*: *Alchemilla*, Api: Apiaceae, *Art*: *Artemisia*, Ast: Asteroideae, Bra: Brassicaceae, Car: Caryophyllaceae, *Cast*: *Castanea*, *Ced*: *Cedrus*, *Cent*: *Centaurea* sp., *Cer*: *Cerealia*-type, Chen: Chenopodiaceae, Cic: Cichorioideae, *Eph*: *Ephedra*, Eric: Ericaceae, Fab: Fabaceae, Herbs: other herbs, *Hum*: *Humulus/Cannabis*, *Kna*: *Knautia*, Lam: Lamiaceae, *Ol*: *Olea*, *Pin*: *Pinus*, *Plant*: *Plantago lanceolata*-type, Poa: Poaceae, *Pol*: *Polygonum aviculare*-type, Prim: Primulaceae, *Qcal*: *Quercus calliprinos*, *Qcer*: *Quercus cerris*-type, *Qsp*: *Quercus* sp., Ran: Ranunculaceae, Ros: Rosaceae, *Sang*: *Sanguisorba minor*-type, *Ses*: *Sesamum*, Shrubs: other shrubs, Trees: other trees, Urt: Urticaceae.

deforestation of Barouk Mountain is also evident in the sediment perturbation of the Aammiq wetland.

This deforestation since c. 8 ky cal. BP is coeval with the beginning of an increasing and sustained human activity around 8 ky in Eurasia (Ruddiman, 2003). While Mount Lebanon was deforested since the middle of the Neolithic, the Chamsine/Anjar record shows no evidence of human activity on the Anti-Lebanon Mountain.

During this period, no evidence of cultivated species is shown by any pollen record. However, pollen grains of *Olea* are recorded since c. 7.5 ky cal. BP in the Chamsine/Anjar pollen record and since c. 8 ky cal. BP in the Aammiq pollen record. *Olea* pollen grains are known to be easily transported (Bottema and Woldring, 1990), and the low pollen percentages of *Olea* certainly indicate that olive trees grew in another area than the Southern Bekaa Valley. As olive trees grow naturally in the Eastern Mediterranean region (Breton et al., 2006), it is not possible with those records to know whether or not these trees were cultivated in Lebanon during this period.

At the end of the Bronze Age (c. 3.5 ky cal. BP), the decrease in the magnetic susceptibility and in Cichorioideae percentages in the Aammiq sequence (Fig. 5) imply that sediment perturbations in the Aammiq marsh may have stopped. As soil erosion is not anymore recorded, human activity and probably deforestation may have stopped on the eastern part of Mount Lebanon. Conversely, archaeological data (Loffet, 2004) indicate continuous deforestation of Mount Lebanon by the Egyptians during the Iron Age. Deforestation must have been performed in another region than the Barouk Mountain and more palaeobotanical and archaeological

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studies in Lebanon are needed to better comprehend this deforestation-depletion in this part of Mount Lebanon.

During the same period, the increase of *Plantago lanceolata*-type suggests that grazing was certainly practiced in the valley around the Aammiq and Chamsine/Anjar wetlands (Figs. 3 and 4).

Between c. 2 and c. 1 ky cal. BP (beginning of the Roman period), the decrease of *C. libani* and *Q. cerris*-type percentages synchronously with the increase of anthropogenic indicators (mainly *Q. calliprinos*, *Pinus* and *P. lanceolata*-type) (Figs. 3–5) in both pollen records shows the resumption of deforestation on Barouk Mountain and the beginning on Anti-Lebanon Mountain. The increase of these anthropogenic indicators also indicates the intensification of pasture in the Bekaa Valley as they are characteristic of grazed areas (Bottema and Woldring, 1990).

Our results suggest that both Mount Lebanon and Anti-Lebanon Mountain were undergoing deforestation while livestock was grazing in the Bekaa Valley. Cultivated species were not recorded in the pollen records. These results are surprising because the first Neolithic farmers set up, around the end of the Late PPNB, the village of Tell Labweh (Kirkbride, 1969) in the northern part of Lebanon (Fig. 1), and cultivated cereals or olive cultures were expected to be found in pollen records from the Bekaa Valley as on the coast of Lebanon (Morhange et al., 1998-1999) and in Israel during the same period (Schwab et al., 2004). However, cultivated cereals are not easy to recognize in pollen records as they are endemic from the Eastern Mediterranean region (van Zeist et al., 1975). Furthermore, it is also possible that grazing areas were present only in this part of the Bekaa Valley.

From the beginning of the Islamic period to the Modern period, major human impact is recorded on both sites by the increase of perturbation in the pollen record.

The increase of *Q. calliprinos* and *Pinus* on both sites, concomitantly with the decrease of *C. libani* and *Q. cerris*-type, shows that deforestation of both Mount Lebanon and Anti-Lebanon Mountain continued during the Islamic period. Moreover, the work of Chehab (1993) shows that the Chamsine/Anjar marsh was irrigated during this period and that increasing human impact has occurred since the Islamic period in the Central Bekaa Valley.

6. Conclusions

The Fertile Crescent is the birthplace of cultivation and domestication of wild animals. The investigation of two Holocene pollen records and archaeological sites in the Southern Bekaa Valley (Lebanon) provides information aiming for evaluating the human impact on landscapes during the Holocene. Deforestation has occurred since the middle of the Neolithic (c. 8 ky cal. BP) on Mount Lebanon and corresponds to the period of the beginning of deforestation in the Eastern Mediterranean region (Ruddiman, 2003). Deforested areas reduced at the end of the Bronze Age in this region, while grazed areas were present in the Bekaa Valley. During the Roman period, on both Mount Lebanon and Anti-Lebanon Mountain, deforestation is again recorded when livestock grazing was dominating in the Southern Bekaa Valley. No cultivated plants appeared in our pollen records. After c. 1 ky cal. BP, at the beginning of the Islamic period, several human activities, recorded both in pollen records and in archaeological sites, disturb the pollen signal. Our approach, which integrates palynology and archaeology, allows a better understanding of human impact on the environment during the Holocene in Lebanon.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.jaridenv.2008.11.002.

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