

Paléorient

REVUE PLURIDISCIPLINAIRE DE PRÉHISTOIRE ET PROTOHISTOIRE
DE L'ASIE DU SUD-OUEST ET DE L'ASIE CENTRALE

PLURIDISCIPLINARY JOURNAL OF PREHISTORY AND
PROTOHISTORY OF SOUTHWESTERN AND CENTRAL ASIA

2010 36.2

CNRS EDITIONS



NOTES ON ARBORICULTURAL AND AGRICULTURAL PRACTICES IN ANCIENT IRAN BASED ON NEW POLLEN EVIDENCE

M. DJAMALI, N.F. MILLER, E. RAMEZANI, V. ANDRIEU-PONEL, J.-L. DE BEAULIEU,
M. BERBERIAN, F. GUIBAL, H. LAHIJANI, R. LAK and P. PONEL

Abstract: *New pollen evidence from two sites in South-Central Zagros (Lake Maharlou), Southwestern Iran, and Sahand Mountains (Lake Almalou), Northwestern Iran, provide evidence for the emergence of tree cultivation in Southwestern Iran since the 3rd and 2nd millennia BC and upland agricultural activities in Northwestern Iran since 5th to 3rd centuries BC. Juglans cf. regia could have been cultivated firstly at ~2500 BC and became more extensively cultivated since ~1200 BC. Platanus cf. orientalis was also probably cultivated very early at ~1900 BC during the Middle Elamite period (2800-550 BC) and became more widely cultivated from ~1200 BC along with Juglans. The latter arboricultural events could have resulted from the establishment of great urban civilizations in Southwestern Iran. The rise of the Persian Empires seems to have been associated with a large-scale agricultural revolution over the Iranian Plateau. During the Persian Achaemenid Empire (550-330 BC) tree cultivation expanded in the Lake Maharlou area and agricultural practices expanded into upland areas in Lake Almalou area probably due to socio-economic stability and the development of water exploitation and irrigation techniques. The Parthian (250 BC-225 AD) and Sassanian (224-642 AD) periods were also associated with tree cultivation practices in Lake Maharlou area but to a lower extent comparing to the Achaemenid period. In the Lake Almalou area, the Parthian period saw no spectacular agricultural event at least partly due to political and socio-economic instability caused by conflicts with Romans over Armenia. The socio-economic stability and further development in agricultural techniques during the Sassanian Empire could, however, favor again the large-scale tree cultivation practices in Northwestern Iran. The Post-Islamic period is characterized by reduced agricultural activities in the Iranian Plateau most probably due to political instability caused by numerous invasions by Arabs, Turks and Mongols. The last significant agricultural event recorded in the Lake Almalou pollen record is the appearance of Ricinus communis cultivated since the beginning of the Safavid Empire (1501-1722 AD).*

Résumé: *De nouvelles données polliniques provenant de deux sites dans les montagnes du Zagros (lac Maharlou, Sud-Ouest l'Iran) et de Sahand (lac Almalou, Nord-Ouest de l'Iran), apportent des indications sur l'émergence de l'arboriculture dans le Sud-Ouest iranien depuis les III^e et II^e millénaires av. J.-C., et sur les pratiques agricoles dans les hautes terres du Nord-Ouest iranien du V^e au III^e siècles av. J.-C. Juglans cf. regia fut probablement cultivé dès 2500 av. J.-C., puis plus extensivement à partir de 1200 av. J.-C. environ. Platanus cf. orientalis fut probablement cultivé précocement, vers 1900 av. J.-C., au cours de la période élamite moyenne (2800-550 av. J.-C.), et il devint plus largement cultivé à partir de ca. 1200 av. J.-C., parallèlement à la culture de Juglans. Ces innovations agricoles ont pu résulter du développement des grandes civilisations urbaines dans le Sud-Ouest de l'Iran. L'émergence de l'Empire perse semble être associée à une révolution agraire à grande échelle sur le plateau iranien. Sous l'Empire achéménide (550-330 av. J.-C.), l'arboriculture s'est développée dans la région du lac Maharlou alors que l'agriculture atteignait les hautes terres autour du lac Almalou, probablement en raison d'une plus grande stabilité socio-économique et du développement des techniques d'irrigation. Les périodes parthe et sassanide (224-642 de notre ère) ont également vu le développement de l'arboriculture dans la région du lac Maharlou, mais dans une moindre mesure que lors de la période achéménide. Dans la région du lac Almalou, la période parthe ne témoigne pas de pratiques agricoles spectaculaires, en raison peut-être de l'instabilité politique et socio-économique consécutive aux conflits avec l'Empire romain en Arménie. Sous l'Empire sassanide, la stabilité socio-économique et le renouveau des techniques agricoles ont pu toutefois favoriser le développement à grande échelle de l'arboriculture dans le Nord-Ouest de l'Iran. La période qui suit*

l'arrivée de l'Islam est caractérisée par des activités agricoles moins importantes sur le plateau iranien, très probablement en raison de l'instabilité politique liée aux invasions arabes, turques et mongoles. Le dernier fait agricole significatif enregistré au lac Almalou est l'apparition de Ricinus communis, cultivé dès le début de l'Empire safavide (1501-1722 de notre ère).

Keywords: Agriculture; Tree Cultivation; Pollen; Elamite Dynasties; Persian Empire; Zagros; Azarbaijan; Iran.

Mots-clés : Agriculture; Arboriculture; Pollen; Dynasties élamites; Empire perse; Zagros; Azerbaïdjan; Iran.

Anthropogenic pollen indicators in Holocene pollen diagrams can help document the history of agriculture and land-use practices.¹ In regions with a long history of human settlement such as the Near East, high-resolution and well-dated pollen diagrams further permit inferring the economic conditions associated with some major historical periods and events.² Since the Iranian Plateau is considered to be a main centre of plant and animal domestication³ with a very long history of human activity, pollen investigations can largely contribute to the understanding of its cultural and socio-economic development. In this study, we present new pollen evidence from Northwestern (Lake Almalou, Iranian Azarbaijan)⁴ and Southwestern (Lake Maharlou, Fars Province)⁵ Iran, which provide new insights into the history of plant cultivation and socio-economic evolution in Iran during the last five millennia. We will also compare the new pollen data with available archaeobotanical data from the study areas.

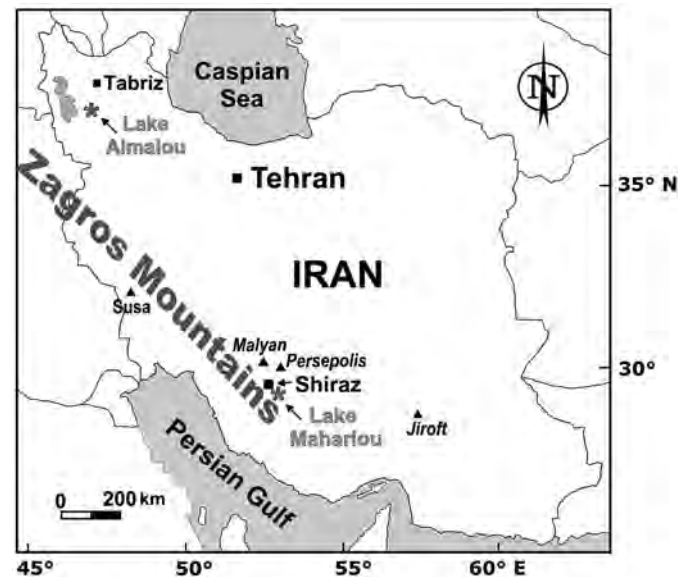


Fig. 1 – Location of Lake Almalou and Lake Maharlou and some archaeological sites mentioned in the text.

POLLEN RECORDS AND CHRONOLOGICAL FRAMEWORK

This paper is based on two pollen diagrams from Lake Maharlou in Southwestern and Lake Almalou in Northwestern Iran (fig. 1). Lake Maharlou is a shallow saline lake situated in the central Zagros Mountains near Shiraz. A pollen diagram covering nearly the five last millennia was constructed from a 1.6 m sediment core retrieved from central part of the lake basin.⁶ Lake Almalou is a peat bog situated in a volcanic crater on the eastern flanks of the Sahand Mountains in Azarbaijan province. A ~3750-year pollen diagram was constructed from a 470 cm sediment core recovered from the edge of the peat.⁷

1. BEHRE, 1981; BOTTEMA and WOLDRING, 1990.
2. HEIM *et al.*, 1997; NEUMANN *et al.*, 2007.
3. ZOHARY and HOPF, 1994; NADERI *et al.*, 2008.
4. DJAMALI *et al.*, 2009a.
5. DJAMALI *et al.*, 2009b.
6. DJAMALI *et al.*, 2009a.
7. DJAMALI *et al.*, 2009b.

Age-Depth models of the cores are presented in figure 2. Whereas no correction for the reservoir effect seems necessary for ¹⁴C ages of Lake Almalou, a correction of ~800 years (fig. 2) has to be applied to the Lake Maharlou ¹⁴C ages because of the reservoir effect induced by high carbonate concentrations in the lake water.⁸ The reader should note that the proposed chronology of agricultural events in Southwestern Iran is therefore based on this calculated 800-year reservoir effect which may be the subject of changes after true correction in future. Simplified pollen diagrams of these two lakes are represented in figure 2 with a selection of major anthropogenic pollen taxa of particular interest for this study.

8. FAYAZI *et al.*, 2007; DJAMALI *et al.*, 2009a.

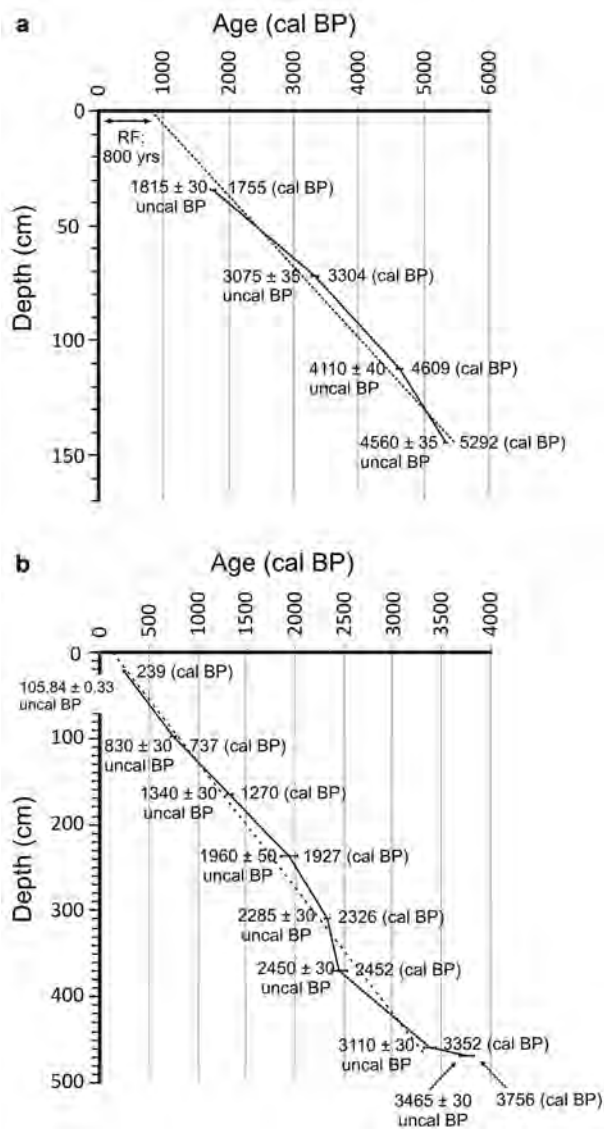


Fig. 2 – Age-depth model for Lakes Maharlou (a) and Almalou (b). For Lake Maharlou, the calibrated ^{14}C ages (right side of the curve) are ~ 800 years older than real ages due to the reservoir effect. This error has been corrected in the chronology of figure 3.

LAKE MAHARLOU BASIN, SOUTH-CENTRAL ZAGROS MOUNTAINS, SOUTHWESTERN IRAN

The historical and archaeological importance of the Lake Maharlou area is evidenced by its proximity (~ 60 km) to Anshan (Tapeh Malyan), the highland capital of the Elamites

(~ 2800 - 550 BC) and Persepolis, the capital of the Achaemenid Empire (550 - 330 BC) (see fig. 1). Whereas pollen variation of anthropogenic herbs, including cereals and ruderals (e.g., *Plantago lanceolata*-type and *Rumex*) do not give much information on past agro-pastoral activities,⁹ the cultivated tree pollen variation displays meaningful trends (fig. 3a). The figure 3a shows a simplified pollen diagram including major pollen taxa of ecological and anthropogenic importance—e.g., *Quercus* (oak), *Pistacia* (pistachio), *Artemisia*, Chenopodiaceae, *Juglans* (walnut), *Platanus* (plane), *Vitis* (grape), and *Olea* (olive). For a more detailed pollen diagram, the reader is referred to M. Djamali *et al.*¹⁰ The chronology of the anthropogenic events in this diagram differs from those proposed by Djamali *et al.*,¹¹ as the ages in the present paper are corrected for reservoir effects (fig. 2a). The calculated reservoir effect is an approximation deduced by the intersection of the trend line of calibrated radiocarbon ages with the line corresponding to core top. The precise value of the reservoir effect remains to be calculated in future by comparison between radiocarbon ages obtained from allochthonous plant remains and/or charcoal grains with those obtained from the bulk sediment.

The first significant anthropogenic event in the Maharlou pollen diagram seems to be the small peak (1.4%) of *Juglans* pollen dated to ~ 2500 BC with its next appearance at ~ 1100 BC (fig. 3a). The former date coincides with the beginning of the Elamite period, the latter with the Late Elamite period. By 1900 BC the first traces of *Platanus* pollen appears during the Middle Elamite period. The aggregated curve of pollen types attributable to the cultivated trees (i.e., *Juglans*, *Platanus*, *Vitis* and *Olea*) becomes continuous at ~ 1200 BC (Late Elamite) and starts increasing at ~ 700 BC (latest Elamite period). The curve shows a prominent peak at around 500-600 BC, suggesting that tree cultivation culminated at the time of the Persian Median and Achaemenid Empires. Archaeological and historical evidence indicate that during the Achaemenid period numerous hydraulic structures such as diversion dams, tunnels, canals, kārīz (qanat) system, and aqueducts were constructed, particularly in the Fars area (Southwestern Iran). Many of these systems still function today.¹² These construction efforts and the associated developments in water management caused an outstanding agricultural development in ancient Iran and would have been a fundamental factor in the intensification of tree cultivation. By ~ 350 BC, cultivated tree pollen declines

9. DJAMALI *et al.*, 2009a.

10. *Ibid.*

11. *Ibid.*

12. MALEKZADEH, 2007; ZAND *et al.*, 2007.

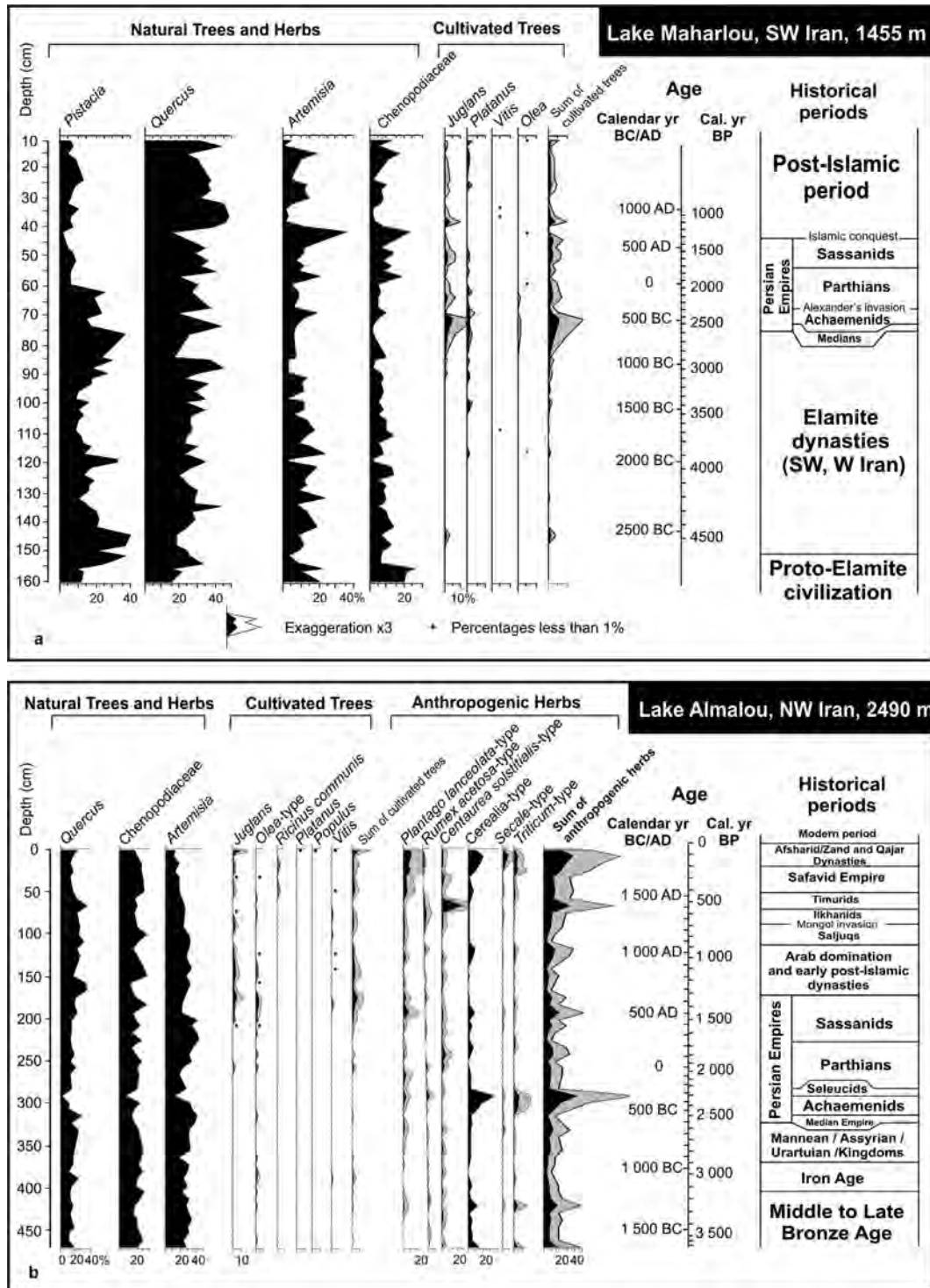


Fig. 3 – Simplified pollen diagrams of Lakes Maharlou (a) and Almalou (b).

and nearly disappears from the pollen diagram. This date coincides with the collapse of the Achaemenid Empire at ~330 BC with Alexander's invasion of Persia. Although the Parthian and Sassanid periods are associated with a small increase of cultivated tree pollen, the tree cultivation never reached again its development experienced during the Achaemenid period. During the middle part of the Parthian period, two significant events can be mentioned in the Lake Maharlou Basin: (i) there appears to have been a large-scale destruction of the natural *Pistacia-Amygdalus* scrub, and (ii) a drought event evidenced by the peaks of *Artemisia* and Chenopodiaceae pollen centered at ~100 AD (fig. 3a). The former event might suggest that in the Zagros Mountains, nomadic pastoral production increased at the expense of settled agriculture during this time interval. Subsequently, a large-scale drought event in the South-Central Zagros seems to be associated with the collapse of agricultural activities during the latest part of the Sassanian Empire and the Islamic conquest. Assessing Post-Islamic agro-pastoral activities is relatively difficult, as no radiocarbon dating is available from the uppermost part of the studied core of Lake Maharlou. However, with the exception of a short episode centered ~900 AD, the pollen diagram shows relatively moderate to low values of cultivated tree pollen during the Post-Islamic period (Middle Ages).

LAKE ALMALOU AREA, SAHAND MOUNTAINS, NORTHWESTERN IRAN

Lake Almalou is located in an upland region relatively far from the main human settlements such as those found in the plains around Lake Urumiyeh (Urmia). Some of the nearest important archaeological sites include Hajji Firuz (6th millennium BC) in the area south of Lake Urumiyeh (~130 km southwest of Lake Almalou),¹³ and Yanik Tapeh (6th millennium BC until the beginning of the 1st millennium BC) (~55 km northwest of Lake Almalou).¹⁴ The Almalou pollen record shows significant variations in both anthropogenic herbs (e.g., cereals and *Plantago lanceolata*-type) and cultivated trees (e.g., *Juglans*, *Vitis*, and *Olea*) (fig. 3b). The figure 2b illustrates a simplified version of the pollen diagram of Lake Almalou with a selection of main anthropogenic herbs, cultivated trees and also the main components of the regional vegetation (*Quercus*, *Artemisia*, and Chenopodiaceae). Based on the variations of these anthropogenic herbs and cultivated

trees, several phases of intensified agriculture can be distinguished and precisely dated thanks to a relatively high resolution radiocarbon chronology.

Apart from two small peaks of cereal-type pollen dated at ~1700 and ~1300 BC (Middle to Late Bronze Age) and a gentle increase of cultivated tree pollen mainly composed of *Olea* pollen centered at ~1100 BC (Iron Age), no significant agricultural event is observed in the prehistoric pollen spectra of Almalou (fig. 3b). At ~500 BC, the first significant and perhaps the most spectacular agricultural event of the study area appears which is characterized by an explosion of cereals, mainly *Triticum*-type pollen associated with the presence of remains of the coprophagous beetle *Aphodius* and the input of detrital sediments into the Almalou peat bog.¹⁵ The presence of such high values of cereal-type pollen (> 40%) suggests that cereal-farming was practiced within the volcanic crater of Almalou, which in turn suggests that agricultural activities were expanded to the upland areas. The finding of *Aphodius* remains attests to grazing within the Almalou crater. The combination of intensive cereal cultivation and stock grazing caused soil erosion and the deposition of detrital sediments into the Almalou peat bog at this time.¹⁶ The decline of cereal farming is coincident with the collapse of Achaemenid Empire and Alexander's invasion.

During the Parthian period, no conspicuous sign of extensive cereal and tree cultivation is observed (fig. 3b) and pastoral nomadism was most probably the dominant mode of life. The abandonment of agricultural activities during the Parthian period can also be attributed to socio-economic instability caused by numerous conflicts between the Persians and Romans over the Armenian kingdom.¹⁷ From the middle part of the Sassanian period, agricultural activities in the form of tree cultivation expanded in Northwestern Iran, with pollen spectra characterized by increased values of *Juglans* and *Vitis*. Whereas walnut and grape can grow under the low winter temperatures of Northwestern Iran, it seems unlikely that olive was planted in the region. However, the olive pollen can be transported over long distances and the pollen curve of olive (*Olea*-type) may indicate its cultivation in the Eastern Mediterranean and/or southern coastal plains of the Caspian and Black seas. In the Eastern Mediterranean, the start of the massive olive cultivation goes back to the Early Bronze Age based on an archaeobotanical investigation in Tell Mastuma, Northwestern Syria.¹⁸

13. VOIGT, 1983.

14. BURNEY, 1961; 1962 and 1964.

15. DJAMALI *et al.*, 2009b.

16. *Ibid.*

17. KHORENATSI, 1978; KURKJIAN, 1964; BOURNOUTIAN, 1993.

18. YASUDA, 1997.

In the Golan Heights, the pollen record of olive cultivation dates back at least to Chalcolithic period but its most extensive cultivation was practiced during the Roman/Byzantine period.¹⁹ Therefore, the *Olea* pollen curve in the Almalou diagram can be interpreted as long distance transport from the olive orchards in the Eastern Mediterranean region and the small *Olea* peak during the late Sassanian period (fig. 3a) correlates with its extensive cultivation during the Roman period. Unlike the Parthians, which were more interested in eastern parts of the Iranian Plateau and the Indo-Pakistani sub-continent, the Sassanian Empire could take the control of the majority of the Near East and brought back a socio-economic stability to Northwestern Iran.

The development of irrigation techniques during the Sassanian Empire²⁰ may have been important for the intensification of arboricultural activities. Our Pollen evidence suggest that after the Islamic conquest of 642-651 AD, the tree cultivation practices declined for more than one century before being resumed at ~780 AD (fig. 3b). A relatively pronounced phase of tree cultivation abandonment can be detected some time ~1100 AD roughly coinciding with the dominance of Saljuqs (Seljuk Empire: 1031-1194 AD). Continuous curve of cultivated trees between 1220 and 1350 AD may correspond to the Ilkhanids which appointed Tabriz as their capital city during 1256-1353²¹ and the totally absence of cultivated tree pollen at ~1420 AD may correspond to the Tamerlane invasions (1381-1405 AD) which devastated the infrastructures and caused agricultural desertion.²²

Around a century prior to the establishment of the Safavid Empire (1501 AD), the agricultural activities began to expand again but only to a limited extent. Two non-exclusive hypotheses can be proposed to explain limited agricultural activities during the Safavids. The first hypothesis is that the severe climatic conditions (low winter temperatures) during the Little Ice Age with maximum influence between 1550 and 1850 AD,²³ made the upland agriculture difficult.²⁴ The second hypothesis is that the numerous conflicts between Safavids and Ottoman Turks could have created a regional socio-economic instability, which in turn favored pastoral nomadism over agricultural activities. A spectacular fruticultural feature of the Almalou pollen diagram is the appearance of *Ricinus* by the onset of Safavid Empire (~1520 AD). During the last two centuries both upland agricul-

tural and pastoral activities were intensified as is inferred from increased values of cereal-type (*Secale*-type and *Triticum*-type) and *Plantago lanceolata*-type pollen (fig. 3b).

DISCUSSION

ON THE ORIGIN OF TREE CULTIVATION IN IRAN

In this section, some aspects of tree cultivation in Southwestern and Northwestern Iran are discussed mainly on the basis of new palynological findings in Lakes Almalou and Maharlou (fig. 3a-b). The emphasis is put on *Juglans* and *Platanus*, the presence of which (in the Southwest) can more certainly be attributed to human activities. Two other major cultivated trees, *i.e.*, *Olea* and *Vitis* are not the subject of a detailed discussion in this study. As mentioned earlier, *Olea* has significant pollen dispersal and is wind-transported over long distances. A good proof for this fact is that its pollen grains in association with some other Mediterranean anemophilous taxa (*e.g.*, *Ephedra* and *Acacia*) can be found in the modern pollen rain as far north as the Fennoscandia.²⁵ *Olea* is not currently grown in Northwestern Iran due to very low winter temperatures and high snowfall. Its presence in the Almalou pollen diagram, can therefore be attributed to a long transportation from its cultivars or natural stands in the Eastern Mediterranean region and Northern Iran.²⁶

In contrast, winters are milder in Southeastern Iran and wild olive trees (*O. aucheri*, *O. ferruginea*) can grow here and there.²⁷ However, the finding of *Olea* pollen in the Maharlou diagram has to be interpreted with caution and the demonstration of olive cultivation may need more archaeobotanical and palynological evidences particularly from the lowland areas of the Persian Gulf coasts and the Khuzestan Plain. Similarly, the interpretation of *Vitis* pollen curves in terms of anthropogenic pollen indicators is difficult. According to available archaeobotanical data, the grapevine (*Vitis vinifera* L.) might have first been cultivated in the region of its natural distribution in the 6th millennium BC. Domestication of a genetically altered type possibly happened during the 4th millennium BC, but widespread cultivation outside the natural distribution area of the vine occurred during the 3rd millennium BC.²⁸ It is known

19. NEUMANN *et al.*, 2007.

20. RAHIMI-LARIDJANI, 1988; ROSHANI NIA *et al.*, 2007.

21. BOYLE, 1968; WILBERT, 1955; HILLENBRAND, 1999.

22. BOYLE, 1968.

23. BRADLEY *et al.*, 2003.

24. DJAMALI *et al.*, 2009b.

25. HJELMROOS and FRANZÉN, 1994.

26. DJAMALI *et al.*, 2009b.

27. MURRAY, 1968.

28. MILLER, 2008.

that the grapevine is extremely under-represented in modern pollen rain and even very low pollen percentages can indicate the existence of nearby vineyards.²⁹ The low values of *Vitis* pollen in the Maharlou pollen diagram may thus suggest the local presence of cultivated grapevines. Nearby, even though Lake Almalou is close to the natural habitat zone for the vine, for the late periods considered here, it is likely that the *Vitis* pollen comes from cultivated plants.³⁰ The pollen grains in Northwestern Iran could also have been produced by wild grape (*Vitis vinifera* subsp. *sylvestris*) which has also a wide distributional range in Southwestern Asia.³¹

Juglans regia L. (Persian Walnut)

Juglans pollen in both Almalou and Maharlou diagrams is most probably produced by *Juglans regia*. Nowadays, the Persian walnut grows wild in mesic temperate deciduous forests of the Balkans, Northern Turkey, Euxino-Hyrcanian region, and Central Asia.³² *Juglans regia* in association with *Acer monspessulanum* (maple) can sometimes form well developed forest stands in the mountain areas of Koppeh-Dagh and Kyrgyzstan.³³ The original natural distribution area of *Juglans regia* is most probably the Eastern Caucasus, Hyrcanian region in Northern Iran and the Koppeh-Dagh Mountains in Northeastern Iran.³⁴ Pollen evidence from the Balkans and Northwestern Turkey suggest that *Juglans regia* was introduced into the European Continent from Anatolia some time in the 2nd millennium BC, i.e., 3400-3200 cal. BP.³⁵ In Central Asia, despite *Juglans* forming large forested areas, its palynological record goes back only to 2000 cal. BP and is supposed to be of anthropogenic origin.³⁶ Based on these pollen evidence and modern geographical distribution, D. Zohary and M. Hopf³⁷ suggest that the domestication of walnut would have most likely taken place in Northwestern Turkey, the Caucasus or Northern Iran.

The archaeobotanical record of *Juglans* in the Near East is thin; prior to the 1st millennium BC, we know of only one report of *Juglans* wood, from the aceramic site of Nemrik, Iraq.³⁸ Two artifacts made of walnut wood have been reported

from graves at Uruk during the Neo-Babylonian period (~626-529 BC).³⁹ Also, several sites dating to Hellenistic, Roman, and later times that are mentioned in the databases organized by H. Kroll⁴⁰ and S. Riehl⁴¹ have walnut. Walnut has never been found in archaeological sites of Eastern and Southeastern Iran (Shahr-I Sokhta in Sistan and Konar Sandal in Kerman).⁴² In Northern Iran, the past occurrence of *Juglans regia* can be demonstrated by the discovery of a wood piece found at 475-477 cm depth of a sediment core from Lake Estakhr-Posht in Northern Iran (36° 28' 00"N, 53° 27' 55", 656 m asl). Radiocarbon dating yields the age of ~1817 ± 65 cal. BP or ~65 AD (unpublished data) correlating to the Middle Parthian period (~250 BC-225 AD). However, in the absence of other pollen and archaeobotanical data from the site, it is difficult to judge whether *Juglans regia* was native to that area or brought in through cultivation.

Given the rarity of wood charcoal and nuts of *Juglans* in the archaeobotanical assemblages of the Near East,⁴³ the pollen evidence can provide valuable information on the past cultivation practices of this tree. According to some authors, *Juglans* is a prolific pollen producer, so if it grew in an area, its pollen is easily found.⁴⁴ Other studies suggest that *Juglans* is an intermediate pollen producer.⁴⁵ However, in the majority of modern pollen samples of the Middle East where walnut is currently cultivated, the modern pollen percentages are very low, so that the pollen percentages as low as < 1% (and < 0.5% according to the unpublished data of third author) may indicate walnut cultivation not far from the pollen sites.⁴⁶ The values of walnut pollen percentages reported in the pollen diagrams of Almalou and Maharlou exceed these low values and strengthen the hypothesis that the tree was cultivated in the area. In the pollen diagrams of Asia Minor and Balkans, walnut pollen appears and starts increasing since the Late Bronze Age and forms an important continuous curve during the so-called "Beyşehir Occupation" phase between ~1600 to 1400 BC.⁴⁷ In several Holocene pollen diagrams from Georgia the walnut pollen appears only recently (e.g., the oldest record is as old as ~460 BC in Lake Imera in Southern Georgia).⁴⁸

29. TURNER and BROWN, 2002.

30. DJAMALI *et al.*, 2009a-b.

31. ZOHARY and HOPF, 1994.

32. *Ibid.*

33. BEER *et al.*, 2007.

34. ZOHARY, 1973; BROWICZ, 1976.

35. BOTTEMA, 1980; BOTTEMA and WOLDRING, 1990.

36. BEER *et al.*, 2008.

37. ZOHARY and HOPF, 1994.

38. Citing R. Gale, KOZŁOWSKI, 2002: 90.

39. NESBITT and POSTGATE, 2001.

40. www.archaeobotany.de

41. www.cuminum.de/archaeobotany

42. M. Tengberg, personal communication.

43. E.g., see WILLCOX, 1974 and 1991.

44. BOTTEMA and BARKOUDAH, 1979; BEER *et al.*, 2007.

45. TORMO MOLINA *et al.*, 1996.

46. BOTTEMA and WOLDRING, 1990; VERMOERE *et al.*, 2001.

47. BOTTEMA and WOLDRING, 1990.

48. KVAVADZE and CONNOR, 2005.

In Southeastern Turkey, walnut is recorded in a pollen diagram from Lake Van since ~2100 varve years ago.⁴⁹ Its appearance in the Holocene pollen diagram of Lake Urmia appears to be approximately contemporaneous with Lake Van.⁵⁰ In Lake Zaribar (Zeribar) located in the Iranian Kurdistan, the first appearance of *Juglans* pollen seems to have occurred more recently and is dated to $\sim 2240 \pm 150$ ¹⁴C BP (~ 350 -260 BC).⁵¹ In the Golan Highlands, the walnut pollen forms a relatively continuous low percentage curve during the Hellenistic/Seleucid period.⁵² In Ghab Valley (Northwestern Syria), *Juglans* appears since the Early Bronze Age but is represented by low pollen percentages all along the diagram.⁵³ In Central Asia (Kyrgyzstan), the appearance of *Juglans* pollen occurred later at ~ 2000 years ago⁵⁴ during the reign of Parthian Empire in Iran and in Central Asia.

In the pollen diagram of Lake Maharlou, the first occurrence of *Juglans* (fig. 3, table 1) seems to predate its record in the pollen diagrams of Anatolia and the Balkans by ~ 1000 years.⁵⁵ Hence, if the suggested record of *Juglans* pollen proposed in this study is confirmed by other pollen and archaeobotanical evidence in the future, it would have significant implications in understanding the history of arboriculture in the Near East. The southeastern part of Iran is outside the original natural geographical range of *Juglans regia*.⁵⁶ It would, therefore, have been introduced from Northern Iran during the 3rd or 2nd millennia BC. Such introduction may be linked to the invasion of Iranian Plateau by Indo-Iranian tribes of Central Asia during the 2nd and 1st millennia BC. According to the Maharlou pollen diagram, the establishment of Persians in Southwestern Iran (Persis, Pars or Arabized Fars) during the 5th century BC is accompanied with the maximum expansion of *Juglans* cultivation as well as *Platanus*. It seems that Persian Empire was an important center for cultivation and export of walnut in the old world. According to Pliny the Elder (23-79 AD), the knowledge of cultivation and oil production from walnut has been transferred from the Persians to Greeks and then to Romans.⁵⁷ *Juglans* can tolerate low winter temperatures in mountain areas but needs some watering in the summer months and cannot stand long summer dry

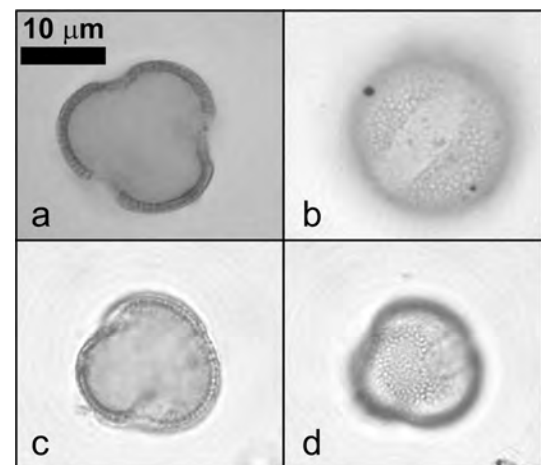


Fig. 4 – Light microscopic photos of a sub-fossil *Platanus* pollen found at 60 cm depth. **a**, polar view; **b**, equatorial view; **c-d**, oblique views.

months of Southwestern Iran.⁵⁸ The development of irrigation and other water management systems, like *kārīz*/*qanat* systems in the interior parts of Iranian Plateau⁵⁹ could have supplied the needed water to irrigate the *Juglans* as well as other fruit tree gardens and orchards.

***Platanus orientalis* L. (Oriental Plane Tree)**

The *Platanus* pollen found in the Lake Maharlou core was produced by *P. orientalis* L. because this species is considered as the only representative of the genus in the Old World.⁶⁰ Determination is reliable due to both characteristic morphological features of the *Platanus* pollen and the excellent preservation state of pollen grains due to hypersaline conditions of the lake water (fig. 4). The isolated conditions of our pollen extraction laboratory (*Institut méditerranéen d'écologie et de paléoécologie*) and also the time of chemical treatments in January, exclude any possibility of contamination from the modern pollen rain. Hence, it is certain that the pollen attributed to *Platanus* in the present study, represents the occurrence of this tree taxon in the study area in the past. As the *Platanus* pollen is present with extremely low pollen values in many modern anthropogenic landscapes in which plane tree is cultivated,⁶¹

49. WICK *et al.*, 2003.

50. BOTTEMA, 1986; BOTTEMA and WOLDRING, 1990.

51. See VAN ZEIST and BOTTEMA, 1977: fig. 24.

52. NEUMANN *et al.*, 2007.

53. YASUDA *et al.*, 2000.

54. BEER *et al.*, 2008.

55. See BOTTEMA and WOLDRING, 1990.

56. ZOHARY, 1973; BROWICZ, 1976.

57. LITTRÉ, 1850: 673.

58. ZOHARY and HOPF, 1994.

59. GOBLOT, 1979.

60. ZOHARY, 1973.

61. *E.g.*, BOTTEMA and BARKOUDAH, 1979; BOTTEMA and WOLDRING, 1990.

Table 1 – Major agricultural events in Southwestern and Northwestern Iranian Plateau inferred from two Late Holocene pollen diagrams from Lake Maharlou Basin (Central Zagros Mountains, Southwestern Iran) and Lake Almalou area (Eastern flanks of Sahand Mountains, Northwestern Iran). *: Calendar years have been calculated from the calibrated radiocarbon ages (cal. BP; fig. 2) but also corrected for the reservoir effect in the case of the Lake Maharlou (compare fig. 2a).

| Agricultural Events | Site | | Time | | Historical Period |
|--|--------------------|-------------------|------------------|----------------------|-------------------------------|
| | Maharlou (SW Iran) | Almalou (NW Iran) | Calendar Year | Calibrated Year BP* | |
| Modern expansion of upland agriculture and intensified pastoralism | | + | ~1700 AD onwards | ~250 cal. BP onwards | After Safavids |
| Appearance of <i>Ricinus</i> | | + | ~1500 AD | ~450 cal. BP | Safavid Empire |
| Expansion of tree cultivation | | + | ~700-450 AD | ~1500-1250 cal. BP | Sassanid Empire |
| Expansion of upland agriculture (cereal farming and pastoral activities) | | + | ~500-270 BC | ~2450-2220 cal. BP | Achaemenid Empire |
| Maximum tree cultivation | + | | ~600-400 BC | ~2550-2350 cal. BP | Median and Achaemenid Empires |
| Expansion of tree cultivation | + | | ~700 BC | ~2700 cal. BP | Late Elamite |
| Beginning of continuous curve of cultivated trees (<i>Juglans</i> , <i>Platanus</i> , <i>Vitis</i> and probably <i>Olea</i>) | + | | ~1200 BC | ~3100 cal. BP | Late Elamite |
| First appearance of <i>Platanus</i> | + | | ~1900 BC | ~3900 cal. BP | Middle Elamite |
| First appearance of <i>Juglans</i> | + | | ~2500 BC | ~4500 cal. BP | Early Elamite |

it is hard to consider its low values in Maharlou record as a natural long-distance transportation. The continuous nature of plane pollen curve in Lake Maharlou pollen sequence, further corroborates this hypothesis.

A long history of cultivation makes it difficult to determine the original natural distribution area of *P. orientalis* L.⁶² Its modern distribution range comprises the Eastern Mediterranean region (Balkan Peninsula, Turkey, Lebanon, Syria, and Crete), some Western Irano-Turanian countries (Afghanistan, Pakistan, Iran, Iraq, and Turkey), southeastern province of the Euro-Siberian region (Iran and the Caucasus) as well as some districts of the Himalayan province.⁶³ In Iran, *P. orientalis* is considered as native to the northern part of the country, and perhaps also to Kurdistan.⁶⁴ Sub-spontaneous trees in Afghanistan seem to be feral specimens escaped from old cultivations.

Perhaps the oldest archaeobotanical record of plane tree is the wood charcoal remains attributed to *Platanus* found in the Neolithic site Çatalhöyük East in the Konya Basin, South-Central Anatolia dated at ~9300 cal. BP.⁶⁵ In the Lake Van

pollen records (Eastern Anatolia), *Platanus* pollen is also present with very low percentages since the Early Holocene with two isolated occurrences being even older and dating back to the Lateglacial period.⁶⁶ These old occurrences of plane tree pollen suggest that the tree may have played an important role in the riparian forests of the Anatolian Plateau during the Lateglacial and Holocene. Intensified exploitation of riparian woods by man during the historical period would have then decreased or almost completely destroyed the natural stands of *Platanus* in the Eastern Anatolian Plateau.⁶⁷ In Iran, although no traces of *Platanus* can be detected in the pollen diagrams of Lakes Zeribar and Mirabad,⁶⁸ the plane pollen occurs two times in the pollen diagram of Lake Urmia.⁶⁹ First occurrence dates back to the Lateglacial and is represented by an isolated small peak and the second occurrence dates back to almost the same time as *Juglans i.e.*, during the late 3rd millennium BC. In the pollen diagrams of the Anatolian Plateau and Balkans, *Platanus* appears simultaneously with *Juglans* during the “Beyşehir Occupation” phase (~1600-1400 BC).⁷⁰

62. TOWNSEND and GUEST, 1980.

63. ZOHARY, 1973.

64. RECHINGER, 1966.

65. ASOUTI and HATHER, 2001.

66. WICK *et al.*, 2003.

67. *E.g.*, WILLCOX, 1974.

68. VAN ZEIST and BOTTEMA, 1977.

69. BOTTEMA, 1986.

70. BOTTEMA and WOLDRING, 1990.

The appearance of *Platanus* in the Maharlou pollen diagram (fig. 3a) at the middle part of the Elamite dynasties is almost contemporaneous with its charcoal remains found at Malyan prehistoric site located at some 70 km northwest of Lake Maharlou in the Kur River Basin (fig. 1). N.F. Miller⁷¹ reports the charcoal of *P. orientalis* from archaeological deposits of Kaftari period in Malyan dated between ~2200-1600 BC which corresponds to the Early to Middle Elamite period. It is noted that Malyan is considered as the highland capital and Susa as the lowland capital of the Elamite dynasties. The quasi-simultaneous appearance of both pollen and charcoal of *P. orientalis* in the Fars region suggest that the cultivation of *P. orientalis* could have been started by Elamites some 4,000 years ago in the Southern Zagros Mountains. The plane tree cultivation was then followed particularly by Achaemenids. The tree may have played an essential role in the famous royal gardens of the Persian kings and might have been widely used for construction purposes. Many charcoal fragments of oriental plane tree have been documented for Mleiha site, located in the United Arab Emirates, at ~400-200 AD.⁷² This suggests that its timbers would have most probably been imported by the Sassanians that took the control of southern coasts of the Persian Gulf area and dominated marine trade during the Pre-Islamic Era.⁷³

***Ricinus communis* L. (Castor-Oil)**

The most recent arboricultural event recorded in the pollen diagram of Almalou is the appearance of *Ricinus* pollen at the beginning of the Safavid period (~1502 AD). The occurrence of *Ricinus* pollen has already been reported from sub-recent sediments of Lake Urmia.⁷⁴ The origin of *Ricinus* is most likely the sub-tropical regions of Africa and its cultivation by man is believed to date back to the Ancient Egyptians.⁷⁵ In Iran, it has been reported as a sub-spontaneous plant in the southern part of Iran and in Baluchistan (Southeastern Iran) by E. Boissier.⁷⁶ It is possible that *Ricinus* has been introduced by the Persians during the Safavid era when marine trade with Arabia and Eastern Africa developed *via* the Persian Gulf. Its introduction *via* Ottoman Empire seems less possible as no trace of *Ricinus* cultivation is recorded in Eastern Anatolian pollen diagrams.⁷⁷

71. MILLER, 1985.

72. TENGBERG, 2002.

73. DARYAEE, 2003.

74. BOTTEMA, 1986.

75. DE CANDOLLE, 1967; MANNICHE, 1989.

76. BOISSIER, 1875.

77. *E.g.*, BOTTEMA and WOLDRING, 1990; WICK *et al.*, 2003.

UPLAND AGRICULTURE IN NORTHWESTERN IRAN

The pollen diagram of Lake Almalou provides the first direct evidence for upland farming in Iran. Marginal for agriculture, upland areas are considered to be more suitable for pastoral activities. The pattern of upland agriculture abandonment is mainly determined by climate, but the success of other agricultural practices can be improved by careful site selection, resource management, social interactions, and the adaptive capacity of the local human communities.⁷⁸ As the essential climatic parameters that control plant cultivation represent their extreme values in high altitudes, even minor climatic fluctuations could make the environmental conditions unfavorable for agricultural practices particularly those extensively practiced in these regions. This could have been the case during the Little Ice Age, most severe during the interval between 1550 and 1850 AD.⁷⁹ Cultural adaptations allow many upland agricultural communities to respond flexibly to changing climatic conditions, and the Little Ice Age did not always perceptibly affect upland agriculture in other parts of the world.⁸⁰

The political and socio-economic conditions of societies in lowland areas can indirectly influence the human activities in higher mountain areas. One implication of the important upland agricultural event of the Achaemenid period (550-330 BC) is the likely establishment of year-round human settlements in the upland areas of Northwestern Iran, probably indicating a shift from pastoral nomadism to sedentary agriculture under the rule of the Achaemenids. This could at least partly be related to stable socio-economic conditions of Northwestern Iran that prevailed. Ameliorated climatic conditions, such as higher winter temperatures and/or higher spring/summer precipitation may also have been a factor. It has been shown that solar activity was stronger during the time interval corresponding to the Achaemenid Empire.⁸¹ The onset of the Achaemenid period marks the end of a “rapid climate change” at ~3500-2500 cal. BP, which is characterized by higher activities of Siberian Anticyclone and glacial advances in North and South Hemispheres.⁸² This may have increased winter temperatures in Northwestern Iranian highlands and thereby permitted the establishment of human settlements at higher elevations. High resolution palaeoclimatic data from the study

78. O'ROURKE, 2006; DAVIES, 2007.

79. BRADLEY *et al.*, 2003.

80. DAVIES, 2007.

81. *E.g.*, VONMOOS *et al.*, 2006.

82. MAYEWSKI *et al.*, 2004.

area is needed before giving a firm conclusion about a natural (climatic) and/or anthropogenic origin for this agricultural event. The most recent upland agricultural phase recorded in the Almalou record starts by the end of the Little Ice Age and the beginning of recent global warming related to Industrial revolution. The advent of mechanized agriculture and population explosion has certainly favored the intensification of agriculture during the last century.

CONCLUSIONS

Palynological investigations of the Holocene sediments in wetlands of Iran provide complementary information to archaeological data for understanding the history of plant cultivation and agricultural and land-use practices. Pollen variations of some cultivated trees such as *Juglans*, *Platanus*, and *Vitis*, permit us to trace the history of their cultivation by ancient peoples. The first cultivation of walnut in Southwestern Iran would have occurred at ~2500 BC at the beginning of the Elamite period. The present data, completed with a review of pollen records of Southwestern Asia and Southeastern Europe, may lead us to the conclusion that the domestication of walnut occurred in Iran and/or in Anatolian area. At ~1900 BC, the first pollen evidence of *Platanus* plantation emerges during the middle part of the Elamite period. The arrival and settlement of first Persian peoples in Southwestern Iran during the 2nd and 1st millennium BC suggest a likely introduction of these two trees into the Iranian Plateau and marks a key point in shift from pastoral nomadism to sedentary agricultural mode of life. The Persian Empires, particularly the Achaemenid Empire (550-330 BC), witnessed a period of agricultural prosperity in Southwestern Iran. Such agricultural development is manifested in the form of tree cultivation in Southwestern Iran, while in Northwestern Iran it is characterized by the expansion of cereal farming in upland areas. Socio-economic stability, development of water management and irrigation techniques as well as the appreciation for gardens by the Persian Achaemenids seems to have favored the extensive tree cultivation during this period. The expansion of upland agriculture could further have been assisted by less severe climatic conditions in the upland region of Northwestern Iran.

During the Sassanian Empire (224-642 AD) tree cultivation saw a development in Northwestern Iran perhaps due to

both more socio-economic stability compared to the Parthian period (~250 BC-225 AD) and also due to more developed irrigation techniques. The ends of the Achaemenid (~550-330 BC) and the Sassanian Empire (~224-642 AD) are characterized by the decline of agricultural activities most likely due to the temporary socio-economic instability and the destruction of infrastructures, that resulted from the invasion of Alexander the 3rd (331-330 BC), and the Islamic conquest (~642-651 AD). An overall instability during the Post-Islamic period (Middle Ages) prevented the extensive agricultural practices. No remarkable expansion of agriculture is observed in Northwestern Iran during the Safavid Empire (1501-1722 AD) probably due to both socio-economic instability caused by numerous conflicts between Persians and Ottoman Turks and relatively harsh climatic conditions of the Little Ice Age (1550-1850 AD). However, an interesting agricultural feature of the Safavid era is the first cultivation of *Ricinus communis*.

This investigation was only an attempt to use palaeoenvironmental data for a better understanding of the history of agriculture in the Iranian Plateau. The results showed that agricultural practices could have closely been controlled by socio-economic conditions of the past human communities which could in turn be under the control of historical events and climatic conditions. The establishment of great urban settlements and periods of stability in socio-political conditions are mainly associated with major agricultural events. The above picture for past agricultural activities of Iran needs to be completed by new high-resolution pollen diagrams from the archaeologically and historically important areas of Western Iran. The chronology of events should also be checked by different dating methods to avoid age aberration *e.g.*, by reservoir and hard water effects. The Zagros Mountains conceal a good palaeoenvironmental archive in lakes, marshes, and peat bogs many of which being located in old archaeological contexts and should be explored for palaeoecological investigations in future.

ACKNOWLEDGMENTS

This research was partly financed by the Franco-Iranian "Gundishapur Program" and we wish to thank the Iranian Ministry of Science, Research, and Technology, the cultural office of the French Embassy in Tehran, EGIDE, and the Iranian National Institute for Oceanography (INIO) for supporting the field works. We also wish to thank M. Tengberg for archaeobotanical information about sites in Eastern and Southeastern Iran.

Morteza DJAMALI
Philippe PONEL
Valérie ANDRIEU-PONEL
Jacques-Louis DE BEAULIEU
Frédéric GUIBAL

CNRS-UMR 6116 Institut méditerranéen d'écologie et de paléoécologie
 Europôle méditerranéen de l'Arbois
 Pavillon Villemin – BP 80
 13545 Aix-en-Provence Cedex 04
 FRANCE
 morteza_djamali@yahoo.com
 philippe.ponel@univ-cezanne.fr
 valerie.andrieu@univ-cezanne.fr
 jacques-louis.debeaulieu@wanadoo.fr
 frederic.guibal@univ-cezanne.fr

Naomi F. MILLER

Museum Applied Science Center for Archaeology (MASCA)
 University of Pennsylvania Museum
 Philadelphia, Pennsylvania 19104 – USA
 nmiller0@sas.upenn.edu

Elias RAMEZANI
 Department of Forestry
 Faculty of Natural Resources
 Urmia University
 Sero Boulevard – Nazloo – PO Box 165
 Urmia – IRAN
 elias.ramezani@gmail.com

Manuel BERBERIAN
 1224 Fox Hollow Drive Toms River
 New Jersey 08755-2179 – USA
 manuel.berberian@gmail.com

Hamid LAHIJANI
 Iranian National Institute for Oceanography (INIO)
 No. 9 Etemad Zadeh Street
 West Fatemi Avenue
 14155-4781 Tehran – IRAN
 hamidakl@yahoo.com

Razieh LAK
 Geological Survey of Iran
 Meraj Avenue – Azadi Square
 Tehran – IRAN
 lak_ir@yahoo.com

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ISBN : 978-2-271-07210-8 – ISSN : 0513-9345*

Paléorient 36.2 – 2010

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