Sustainability of the early Mediterranean agriculture

Ferrio J.P., Voltas J., Buxó R., Rovira N., Aguilera M., Bort J., Serret M.D., Araus J.L.

in

El Moujabber M. (ed.), Shatanawi M. (ed.), Trisorio-Liuzzi G. (ed.), Ouessar M. (ed.), Laureano P. (ed.), Rodríguez R. (ed.).
Water culture and water conflict in the Mediterranean area

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 83

2008
pages 17-23

Sustainability of the early Mediterranean agriculture

Juan Pedro Ferrio[1], Jordi Voltas[2], Ramon Buxó [3], Núria Rovira[3], Mari Aguilera[4], Jordi Bort[4], Maria Dolores Serret [4], José Luis Araus[5]

[1] Institut für Forstbotanik und Baumphysiologie, Germany.
[2] Department of Crop Production and Forest Science, ETSEA-University of Lleida, Spain.
[3] Museu d'Arqueologia de Catalunya, Spain.
[4] Unitat de Fisiologia Vegetal, Facultat de Biologia, University of Barcelona, Spain.
[5] International Maize and Wheat Center (CIMMYT), Mexico.

Summary. Agriculture is still today the main consumer of water in the Mediterranean. We present two cases studies from the edges of Mediterranean Basin which suggest that already early agriculture in the region was not sustainable but expose to a progressive degradation. One is Tell Halula a site 10 thousand years old from east Mediterranean region of the Fertile Crescent (present-day NE Syria), where Western Agriculture originates. The other site is Los Castillejos, a site from South Spain already active about 6 thousand years before present, occupied soon after the arrival of agriculture to the Western extreme of the Mediterranean. For both cases we present a novel approach to study the sustainability of ancient Mediterranean agriculture that combines the measurement of carbon isotope discrimination ($\Delta^{13}C$) and nitrogen isotope composition ($\delta^{15}N$) along with the assessment of quality traits in fossil cereal grains.

Keywords. Agriculture sustainability – Carbon isotope discrimination – Grain yield – Nitrogen isotope composition – Paleoreconstruction – Soil fertility.

Durabilité de l'ancienne agriculture en Méditerranée

Résumé. *L'agriculture est encore aujourd'hui le principal consommateur d'eau en Méditerranée. Nous présentons deux études de cas sur les bords du bassin méditerranéen qui permettent de suggérer que, déjà très tôt, l'agriculture dans la région n'a pas été durable et soutenable, mais au contraire source d'une dégradation progressive. Le premier site est Tell Halula, un site de 10 000 ans d'ancienneté de la région Est de la Méditerranée du croissant fertile (aujourd'hui N-E de la Syrie), d'où l'agriculture occidentale est originaire. L'autre site est celui de Los Castillejos, un site du Sud de l'Espagne déjà actif depuis environ 6 000 ans avant JC, occupé peu de temps après l'arrivée de l'agriculture dans la partie extrême-occidentale de la Méditerranée. Pour les deux cas, nous présentons une nouvelle approche étudiant la durabilité de l'agriculture méditerranéenne antique, cette approche combinant les mesures de la discrimination isotopique du carbone ($\Delta^{13}C$) et de la composition d'isotope d'azote ($\delta^{15}N$), ainsi que l'évaluation des traits de qualité dans les grains de céréale fossiles.*

Mots-clés: *Durabilité de l'agriculture – Discrimination isotopique du carbone – Rendement en grain – Composition isotopique du nitrogène – Paleoreconstruction – Fertilité du sol.*

I – Introduction

This paper summarizes recent works performed by our multidisciplinary team which illustrate that Mediterranean agriculture was not sustainable but already from its beginnings exposed to a progressive impoverishment of growing conditions probably associated to both local causes such as loss of soil fertility as well as factors of wider nature, either social (e.g. expansion of land cultivation to a less fertilize areas) and wider factors such as regional or global climate change. We have not intended here to develop an exhaustive study, information may be easily gathered from the literature included, but to illustrate through a retrospective approach that environmental sustainability of agriculture is not a new coined issue for concern but something that has been implicit from the very beginning of the agriculture. Information exists on the literature on the

potential agricultural crisis that help to put the end highly developed civilizations in regions as far between them as Mesopotamia or the Mayan. These examples concern to intensive agricultural systems, where irrigation and a hierarchical organization were the common. However far less information exists from sites going back to the beginnings of agriculture, where societies were probably more equalitarian and demographic pressure less threatening. We present two cases studies from the edges of Mediterranean Basin that where cultivate soon after the emergence of agriculture in both regions.

The archaeological site of Tell Halula (36º25'N, 38º10'E, 337 m.a.s.l.), placed in the Mid-Euphrates region (Governorate of Rakka, Syria) about 105 km east of Aleppo and 25 km northwest of Membij. Tell Halula is a representative site for the beginnings of agriculture in the Fertile Crescent, and comprises (to date) three main excavated periods: Middle and Late Pre-Pottery Neolithic B (M-PPNB, 9750 years Before Present -BP- and L-PPNB, 9300 years BP, respectively), and Pottery Neolithic (PN, 8750 BP). The archaeological site was occupied in an uninterrupted way during ca. 2000 years The area is now characterized by an steppe climate, with an average annual rainfall ranging from 255 to 265 mm, mean temperatures from 17.8ºC to 17.9ºC, and an annual ratio between precipitation and evaporative demand varying between 0.15 and 0.17. Present environmental conditions only allow the cultivation of rainfed barley (in just in the flat areas), whereas other more water demanding crops such as durum wheat or grain legumes are only grown if supplementary irrigation is provided

Los Castillejos, is an archaeological site in SE Spain (Granada Province), with a continuous cereal cultivation of *ca*. 1500 years starting soon after the origin of agriculture (*ca*. 4000 BCE) in the region, which comprises six cultural periods: Early, Middle and Late Neolithic, and Early, Middle and Late Copper Age. Latitude, longitude and altitude above sea level of the settlement are 37º 20'02" N, 4º 00'05" W and 900 m respectively. The site has an annual rainfall of about 600 mm and an average monthly maximum and minimum temperature of 21 and 7℃ respectively. The present-day natural vegetation in the region is Mediterranean, with evergreen oak (*Quercus ilex* L.) as the main tree species plus bushy species like the kermes oak (*Quercus coccifera* L.) and herbaceous plants like rosemary, halt and juniper. The land around the archaeological complex is currently extensively cultivated with olive trees and rainfed cereal (wheat and barley). Fruit orchards and horticultural crops are also present where supplementary irrigation is available.

Besides to illustrate the unsustainable nature of early Mediterranean agriculture a further objective of this work is to illustrate how the combination of different reconstruction techniques, based in the analysis of archaeological grains allows getting an overall picture of the agronomical and environmental conditions characterizing these environments. These techniques are novel in Archaeology and represent adaptations of methods commonly used in other disciplines such as ecology, plant physiology or crop breeding.

II – Materials and methods

1. Tell Halula

Using the stable isotope signature of archaeological grains we obtained estimations of grain yield and the water status for the archaeological site of Tell Halula (Araus *et al*., 1999, 2003; Ferrio *et al*., 2005), which could be directly compared with those currently found in the area (Araus *et al*., 2003).

2. Los Castillejos

Crop water status and yield were estimated from $\Delta^{13}C$ (Araus *et al*., 1999, 2003; Ferrio *et al*., 2005) and soil fertility and management practices were assessed from the $\delta^{15}N$ and N content of grains (Aguilera *et al*., 2008). Original grain weight was inferred from grain dimensions (Ferrio *et*

al., 2004a, 2006) and grain N content was assessed after correcting N concentration for the effect of carbonization.

III – Results and discussions

3. Tell Halula

Our estimates for grain yield are similar or even higher than present yields under rainfed conditions (**Fig. 1**); see also Araus *et al*., 2007 and Ferrio *et al*., 2007). Thus, despite the recent agronomic and genetic advances, the better growing conditions prevailing during the Neolithic allowed ancient farmers to obtain relatively high yields (Araus *et al*., 1999). These conditions of early agriculture are probably related with more water available and more fertile soils (Araus *et al*., 1999, 2003, 2007; Ferrio *et al*., 2004b, 2005) related with a lower demographic pressure and the possibility to put under cultivation just the best soils. On the other hand, considering the high yields attained in the past, and the fact that wild species were still rather common in the archaeological context, at least during the PPNB (**Fig. 2**), it is likely that the pressure of agriculture over the soils were smaller in the Neolithic than in present. Nevertheless, a declining trend in grain yield was found for both wheat and barley, suggesting an effect of land degradation. Alternatively increase in the land put under cultivation, therefore expanding agriculture to less fertile soils may be not discarded, even when archaeological evidence does not support a clear boost in population in the upper Mesopotamia until later (see references in Araus *et al*., 2003). The change from a mixed culture of cereals, legumes and flax (probably including some crop rotation or, at least, fallow) to a nearly monoculture regime of cereals might be the cause behind the lost in crop yields, thus resembling the present situation (Ferrio *et al*., 2007).

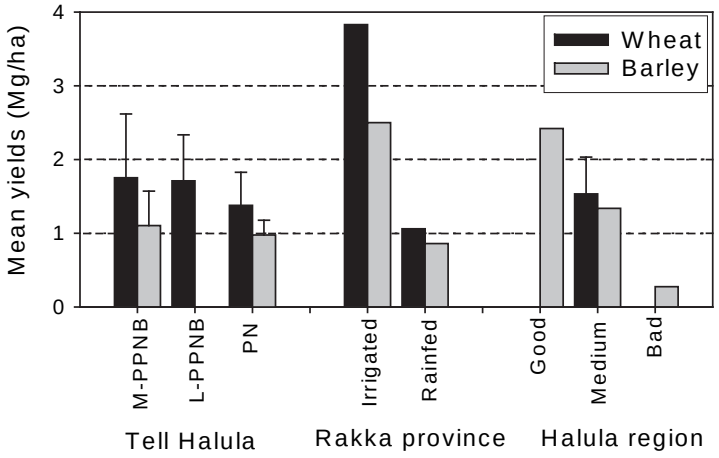

Figure 1. Comparison between estimated yields for the archaeological site of Tell Halula (derived from carbon isotope discrimination of cereal grains, as described in Araus *et al.* (1999); Araus *et al.* (2001); Araus *et al.* (2003), current yields in the Rakka province (1987-1996) for irrigated and rainfed crops, and average yields in "good", "medium" and "bad" years for rainfed barley in Halula region (1994-2004), according to the Membij Farmers Union and Department of Agriculture and the data from the field survey (for wheat only the average value across communities for 2004 is given). M-PPNB, L-PPNB, Middle and Late Pre-pottery Neolithic B; PN, Pottery Neolithic.

4. Los Castillejos

Estimated water conditions (i.e. rainfall) during crop growth remained constant for the entire period. However, grain size and grain yield decreased progressively during the first millennium after the onset of agriculture, regardless of the species, with only slight recovery afterwards (**Fig. 3**). Minimum $\delta^{15}N$ values and grain N content were also recorded in the later periods of site occupation (**Fig. 4**). These results indicate a progressive loss of soil fertility, even when the amount of precipitation remained steady (Aguilera *et al*., 2008), thereby indicating the unsustainable nature of early agriculture at this site in the Western Mediterranean Basin.

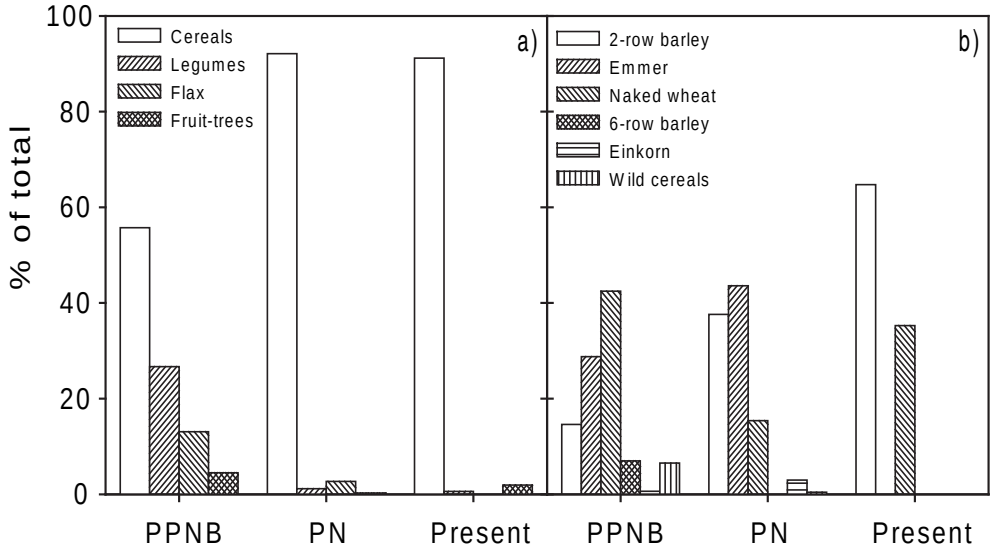

Figure 2. Comparison between the percentage of seeds from each kind of crop that were recovered in the archaeological site of Tell Halula (a surrogate for crop distribution in the past) and the percentage of land currently dedicated to each crop, as derived from Table 1 PPNB, Pre-pottery Neolithic B; PN, Pottery Neolithic.

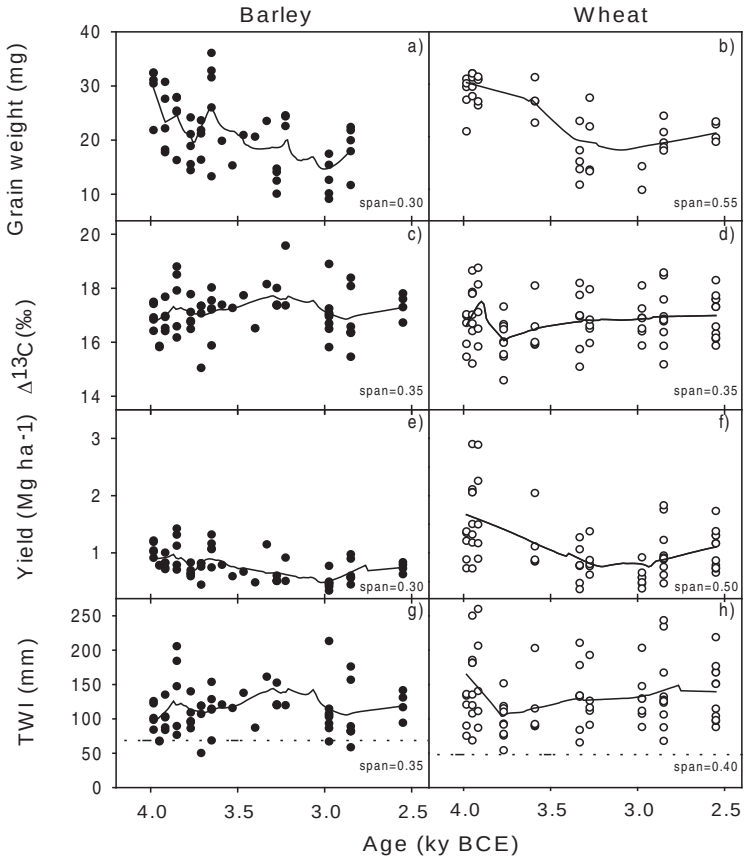

Figure 3. Pattern of changes through time in grain size (a, b), carbon isotope discrimination ($\Delta^{13}C$) (c, d), grain yield (e, f) and total water input during grain filling (g, h) in barley and wheat grown in Los Castillejos. Data spans from the beginning of agriculture in the SE Spain (Neolithic) to the Calcolithic-Copper Age. Trend lines depict locally weighted least-squares regression curves (LOESS) fitted to the data. Water input and grain yield were estimated from $\Delta^{13}C$ values of recovered archaeological kernels. Broken lines refer to the present day water input for barley and wheat in the area. All the analyses and calculations were derived from charred grains recovered at Los Castillejos. Barley dotted circles; wheat, open circles. Redrawn from Aguilera *et al*. (2008).

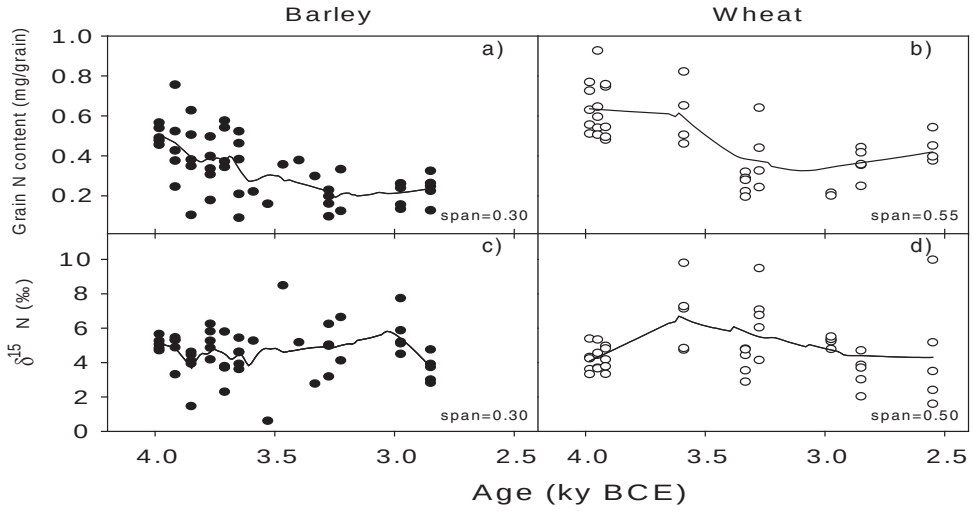

Figure 4: Pattern of changes through time in total N content per grain (a, b) and $\delta^{15}N$ (c, d) in charred barley and wheat grains recovered at Los Castillejos. Trend lines depict locally weighted least-squares regression curves (LOESS) fitted to the data. Total N content was calculated for each grain as the product between grain weight and N concentration of charred grains. Barley dotted circles; wheat, open circles. Redrawn from Aguilera et al. (2008).

IV – Conclusions

We can conclude that early agricultural systems in the Mediterranean were probably not sustainable, but exposed to a progressive lost of efficiency. In the case of Los Castillejos this pattern does not appear necessarily to be related to changes in water availability during cultivation, but rather to decreased soil fertility, particularly for wheat, the main annual crop in Mediterranean agricultural system. In the case of Tell Halula a declining trend in water status and grain yield of cereals, suggesting an effect of land degradation already starting during the Neolithic. Therefore our results reinforce the negative role of early agricultural activities shaping the environmental and ecological conditions in the Mediterranean.

Acknowledgements

This work was partly supported by the CICYT grant CGL2005-08175-C02 BOS and the European Project INCO Melia (Coordination Action 517612).

References

Aguilera, M., Araus, J.L., Voltas, J., Rodriguez-Ariza, M.O., Molina, F., Rovira, N., Buxó, R. and Ferrio, J. P., 2008. Stable carbon and nitrogen isotopes and quality traits of fossil cereal grains provide clues on sustainability at the beginnings of Mediterranean agriculture. Rapid Commun. Mass Sp., 22: 1-11.

Araus, J.L., Febrero, A., Catala, M., Molist, M., Voltas, J. and Romagosa, I., 1999. Crop water availability in early agriculture: evidence from carbon isotope discrimination of seeds from a tenth millennium BP site on the Euphrates. *Global. Change Biol.*, 5: 201-212.

Araus, J.L., Slafer, G.A., Buxó, R. and Romagosa, I., 2003. Productivity in prehistoric agriculture: physiological models for the quantification of cereal yields as an alternative to traditional approaches. *J. Archaeol. Sci.*, 30: 681-693.

Araus, J.L., Ferrio, J.P., Buxó, R. and Voltas, J., 2007. The historical perspective of dryland agriculture: Lessons learned from 10000 years of wheat cultivation. *J. Exp. Bot.,* 58: 131-145.

Ferrio, J.P., Alonso, N., Voltas, J. and Araus, J.L., 2004a. Estimating grain weight in archaeological cereal crops: a quantitative approach for comparison with current conditions. *J. Archaeol. Sci.,* 31: 1635-1642.

Ferrio, J.P., Bort, J., Voltas, J. and Araus, J.L., 2004b. Past climate and agricultural water management in the Mediterranean inferred from carbon isotope discrimination in archaeological plant remains. *Options Mediterraneennes* Série B 48: 289-296.

Ferrio, J.P., Araus, J.L., Buxó, R., Voltas, J. and Bort, J., 2005. Water management practices and climate in ancient agriculture: inference from the stable isotope composition of archaeobotanical remains. *Veg. Hist. Archaeobot.*, 14: 510-517.

Ferrio, J.P, Alonso, N., Voltas, J. and Araus, J.L., 2006. Grain weight changes over time in ancient cereal crops: potential roles of climate and genetic improvement. *J. Cereal Sci.*, 44: 323–332.

Ferrio, J.P., Arab, G., Bort, J., Buxó, R., Molist, M., Voltas, J. and Araus, J.L., 2007. Land use changes and crop productivity in early agriculture: comparison with current conditions in the mid-Euphrates valley. Options Méditerranéennes, Séries B 59: 167-174.