Title

One Sea but many Routes to Sail. The early maritime dispersal of Neolithic crops from the Aegean to the western Mediterranean.

A. de Vareilles[a], L. Bouby[b], A. Jesus[c], L. Martin[d], M. Rottoli[e], M. Vander Linden[f] and F. Antolín[c]

[a]Affiliated Researcher to the McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, UK
[b]ISEM - UMR 5554, CNRS/Université Montpellier/EPHE/IRD, Montpellier, France
[c]Integrative Prehistory and Archaeological Science, Department of Environmental Sciences, University of Basel, Spalenring 145, 4055 Basel, Switzerland
[d]University of Geneva, Laboratory of prehistoric archaeology and anthropology, Geneva, Switzerland & UMR 5204 EDYTEM, University of Savoie Mont-Blanc, Le Bourget-du-Lac, France
[e]Laboratorio di Archeobiologia, Musei Civici di Como, Italy
[f]Department of Archaeology, University of Cambridge, Cambridge, UK

Corresponding author: A. de Vareilles (ak.vareilles@gmail.com)

Abstract

This paper explores the first maritime westward expansion of crops across the Adriatic and the northern coast of the western Mediterranean. Starting in Greece at *c*.6500 cal BC and following the coastline to the Andalusian region of Spain to *c*.4500 cal BC, the presence of the main cereal, pulse, oil and fibre crops are recorded from 122 sites. Patterns in the distribution of crops are explored through ubiquity scores, correspondence analysis and Simpson's diversity index. Our findings reveal changes in the frequencies of crops as farming regimes developed in Europe, and show how different crops followed unique trajectories. Fluctuations in the diversity of the crop spectrum between defined areas are also evident, and may serve to illustrate how founder effects can explain some of the patterns evident in large-scale spatio-temporal evaluations. Within the broader westward expansion of farming, regionalism and multi-directional maritime networks described through archaeological materials are also visible in the botanical records.

Keywords

Prehistoric agriculture, crop diversity, Neolithic, archaeobotany, western Mediterranean, Adriatic

Introduction

The first dispersal of Neolithic farmers into Europe took place along two main routes: inland through Bulgaria, Macedonia and the western Balkans, and seaward following the coastlines of the Adriatic and Mediterranean (e.g. Bocquet-Appel *et al*., 2009). The migration of the Neolithic was not a uniform or linear progression but consisted of an advance interrupted by variable pauses of settling and adaptations (Guilaine, 2001, 2013). After reaching the Aegean the spread of farming stopped for *c*.500 years, apparently during a period of Rapid Climate Change (RCC: 6550-6050 cal. BC, Krauss *et al*., 2017). It has been highlighted that the resumed expansion coincided with the end of the 8.2Ka cooling event, after which a climate more favourable to the cultivation of Neolithic crops is thought to have prevailed (Berger & Guilaine, 2009; Krauss *et al*., 2017: 2; Pilaar Birch & Vander Linden, 2018: 186). Without falling into a dogmatic climatic determinism, it seems clear that climate was one of the many variables influencing the spread of farming. Both Adriatic coastlines were colonized simultaneously (Biagi *et al*., 2005; Bocquet-Appel *et al*., 2009, 2012; Forenbaher and Perhoč, 2015; Mazzucco *et al*., 2017; McClure *et al*., 2014), initially by pioneer seafarers who led the way for larger, more permanently settled communities (Forenbaher and Miracle, 2005; Forenbaher *et al*., 2013). The advance into the Mediterranean also happened as a ‘leap-frog colonization’ (Guilaine, 2017; Zilhão, 2001), though it is calculated to have occurred at a faster rate (Henderson *et al*., 2014: 1297). Westerly sites dated to the early sixth millennium BC, such as Arene Candide in Liguria (Italy), Pont-de-Roque Haute and Peiro Seignado in the South of France and Mas D’Is near Valencia (Spain), are testimony to the rapid advance of the Neolithic

(Manen *et al*., 2018a; García-Puchol *et al*., 2017). Radiocarbon dates and material culture speak of varied temporalities, regionalism and numerous multi-directional maritime excursions through which connections with established settlements were maintained as new coastal areas were settled (Guilaine, 2017, 2018; Manen *et al*., 2018a, 2018b; Rigaud *et al*., 2018).

The Neolithic is recognised through its 'package', consisting of plants and animals domesticated in the Near East, along with particular architectural, tool and ceramic styles and technologies. However, research has shown that whilst the Neolithic 'package' contained all the necessary ingredients for a farming lifestyle, the neolithisation of Europe is better understood through its related yet diverse packages (Guilaine, 2003, 2013, 2018; Manen *et al*., 2018b; Rigaud *et al*., 2018; Thomas, 2003; Vander Linden, 2011). Spatio-temporal variations in the plant and animal diets are evident during the neolithisation of Europe, as packages are seen to change, not only with the spread of farming, but also *in situ* through time as pioneer communities became firmly established (e.g. Antolín *et al*., 2015; Colledge *et al*., 2005; Conolly *et al*., 2011; Fiorentino *et al*., 2013; Gaastra *et al*., 2019; Manning *et al*., 2013; Orton *et al*., 2016; Rottoli and Castiglioni, 2009; Zapata *et al*., 2004). The pioneer Neolithic colonisation of new areas saw a reduction in the range of crops utilized, before additional crops were, in some areas, re-introduced to the original Near Eastern 'package' (Coward *et al*., 2008; Colledge and Conolly, 2007a,b; Colledge *et al*., 2004; de Vareilles, Unpublished; McClatchie *et al*., 2014). Explanations for changes in the suite of cultivated crops, as well as in the importance of particular crop species have been sought through social or cultural forces, and natural adaptations to changing ecological and climatic environments (e.g. Bogaard and Halstead, 2015; Colledge *et al*., 2005; Gaastra *et al*., 2019; Krauss *et al*., 2017; Kreuz *et al*., 2014; Peña-Chocarro *et al*., 2018; Whitford, 2018). Other explanations include the effects of different modes of inheritance, such as neutral drift (change resulting from the random copying of certain traits over others, and innovations – Hahn and Bentley, 2003) and homophily (whereby successful interactions between similar people are more likely than between dissimilar people – McPherson *et al*., 2001: 416), both of which may have resulted in reducing crop diversity during the first neolithisation (Drost and Vander Linden 2018; Pérez-Lozada and Fort, 2011; though see Conolly *et al*., 2008 for negligible effects of drift).

In this article we explore changes in the crop spectrum during the first westward maritime spread across the Adriatic and Mediterranean. Starting at *c*.6500 BC in Greece, we looked for the archaeobotanical traces of the first farmers to colonize the Adriatic and the north-western Mediterranean. Previous studies have focused on specific areas of the Neolithic Adriatic (e.g. Fiorentino *et al*., 2013; Reed, 2015; Rottoli and Castiglioni, 2009) and European Mediterranean (e.g. Antolín and Buxó, 2012; Antolín and Jacomet, 2015; Antolín *et al*., 2015; Bouby *et al*., 2016; Peña-Chocarro *et al*., 2018; Zapata *et al*., 2004), or included coastal zones with inland trajectories for continental-scale analyses (Colledge *et al*., 2005; Coward *et al*., 2008). However, it has been demonstrated that the crops cultivated along the maritime and inland routes of the European neolithisation developed independently (Gaastra *et al*., 2019), and whilst inland developments between SE Europe and the Linearbandkeramik are relatively well understood (Colledge and Conolly, 2007a; Colledge *et al*., 2005; de Vareilles, Unpublished; Krauss *et al*., 2017; Kreuz *et al*., 2005), little has been done to investigate the European maritime route (though see Bogaard and Halstead, 2015; Pérez-Jordà *et al*., 2017). The present study hopes to redress this imbalance by pooling archaeobotanical data from Early Neolithic settlements pertaining to the European maritime route, offering the first statistical approach to describe and interpret developments in the crop spectrum.

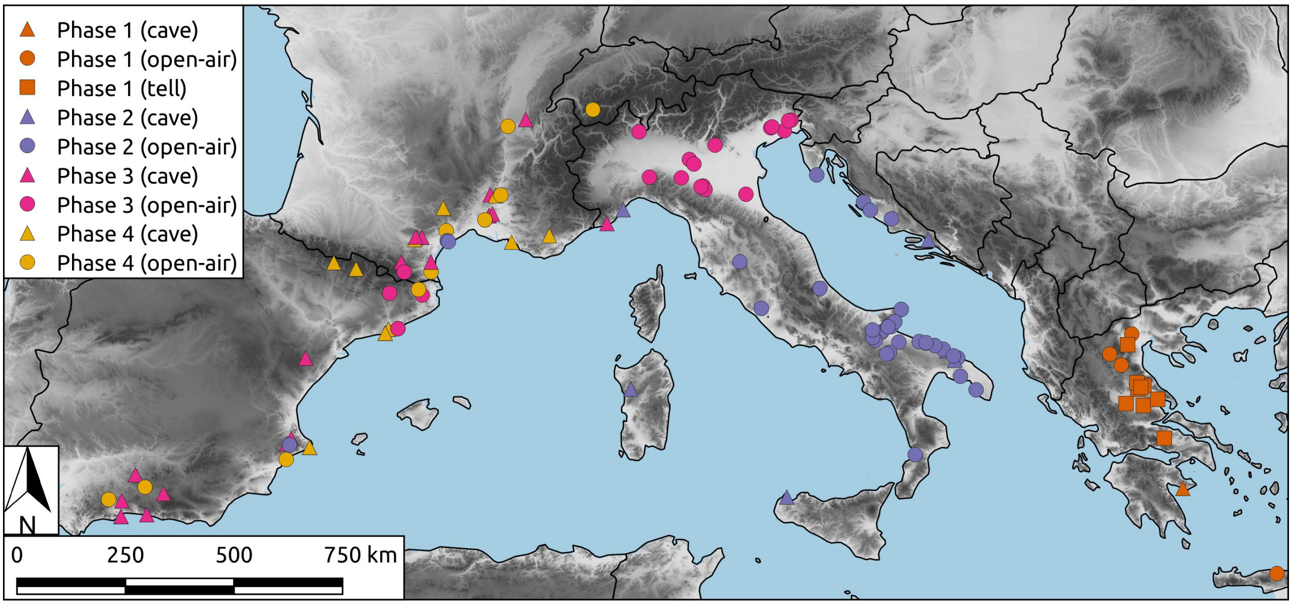


Figure 1: Location of sites used in the study. See Table 1 for the description of phases and Figure 13S for a map with labelled sites

Methodology

One hundred and twenty-two sites from the Aegean to the coast of Málaga, Spain (up to Cueva del Toro at -4.5423 longitude) are included in this research (Table 3). Every effort was made to locate original archaeobotanical reports, although many, particularly from Italy, are not widely published. However, the regional reviews used (referenced in Table 1) are internationally accepted and care was taken to source any re-evaluations of site dates and details. Sites were chosen according to a strict chronological framework to represent the very first European westward maritime dispersal of cultivated crops (Figure 1). The four phases are divided into 500 year brackets, starting at *c*.6500 cal BC, and Phases 1 to 3 roughly correspond to renewed colonizations of coastal areas and the developments of new ceramic expressions (Table 1). Phases 3 and 4 along the western northern Mediterranean are less distinct, representing both pioneer settlements of coastal zones and the second phase of habitation in others (sites 96, 99, 102, 104 and 117). Although sites in Italy that clearly post-date the sixth millennium BC are not included, 13 have broad chronological brackets that span both Phases 3 and 4 (sites 53 to 55 and 57 to 66). The same is true of three French sites (sites 74, 75 and 76). Finds from the site of Balma Margineda (Andorra) are not included because AMS dates obtained from plant remains, all found within a single context, span across the sixth and fifth millennium BC (Manen *et al*., 2018a) and our Phases 2 to 4. However, a naked barley grain was dated to 5665-5555 cal BC (95.4%) and is included in barley finds of Phase 2 (Figure 5). Sites were assigned to a phase following relevant radiocarbon dates where available or cultural attribution as defined in Table 1.

Phase	Chronology (cal. BC)	Extent of the coastal spread	Main archaeological groups
1	c.6500-6100/6000	Greece and Crete	Monochrome, proto-Sesklo
2	c.6100/6000-5500	Dalmatia, South Italy, Sardinia and the Portiragnes area of France	Impressed-Ware, Impresso-Cardial, Guadone
3	c.5500-5000	North Italy and across the northern half of the western Mediterranean	Impressed-Ware, Stentinello, Fiorano, Friuli, Vhó, à Fagninola, Isolino, VBQ (square-mouthed pottery), Gaban, Cardial/Epicardial, Néolithique Ancien Valaisan
4	c.5000-4500	Developments within the western Mediterranean zone	Cardial/Epicardial, Néolithique Ancien Valaisan

Table 1: The chronologies, geographical coverage and cultural entities of Phases 1 to 4

The dataset comprises of 122 site/phases with records of domesticated crops. The crops included in this study are the main cereals and pulses cultivated during the Early Neolithic (Table 2). Opium poppy and flax are also included to document possible early findings. Records of spelt (*Triticum spelta*) and broomcorn millet (*Panicum milliaceum*) are excluded from this study. Low concentrations of spelt suggestive of its presence as a crop contaminant are noted for the Early Neolithic (e.g. Huntley, 1996; Kreuz, 1990; Marinval, 2003b; Sargent, 1987), while the first clear evidence of domestic spelt dates to the Bell Beaker period (Akeret, 2005). Dated millet seeds from Neolithic contexts tend to belong to much later periods, even if the occasional seed (perhaps a weed) is found to be of Neolithic date (Hunt *et al*., 2008; Motuzaite-Matuzeviciute *et al*., 2013). Indeed, millet cultivation in Europe is unlikely to pre-date the Bronze Age (e.g. Filipović and Obradović, 2013: 42-3; Reed, 2015: 612; Stevens *et al*., 2016: 1545; Tafuri *et al*., 2018; Valamoti, 2013).

Crop category	**Species included**
Barley	Grains and chaff of *Hordeum vulgare sensu lato, H. vulgare vulgare, H. vulgare nudum*
Glume wheats	Grains and chaff of *Triticum monococcum* (einkorn) and *T. dicoccum* (emmer)
Free-threshing wheats	Grains and chaff of *T. aestivum/durum/turgidum*
‘New’ glume wheat	Grains and chaff of *T.* cf. *timophevii*, ‘new type’
Lentil	Seeds of *Lens culinaris, Lens* sp.
Pea	Seeds of *Pisum sativum, Pisum* sp.
Grass/red pea	Seeds of *Lathyrus sativus, Lathyrus cicera*
Bitter vetch	Seeds of *Vicia ervilia*
Broad bean	Seeds of *Vicia faba*
Common vetch	Seeds of *Vicia sativa*
Chickpea	Seeds of *Cicer arietinum*
Flax	Seeds of *Linum usitatissimum*
Poppy	Seeds and capsules of *Papaver segiterum/somniferum*

Table 2: Crop taxa included in the study

The recording and publication of archaeobotanical remains from the research area varies greatly, from publications with contextualised and/or quantified data (e.g. Antolín, 2016; Buxó, 1997; Pérez-Jordà and Peñblia-Chocarro, 2013; Reed and Colledge, 2016; Valamoti, 2011), to mere lists of taxa by site (e.g. Fiorentino *et al*., 2013; Marijanović, 2009; Renfrew, 1979; Rottoli and Castiglioni, 2009). Preservation also varies; whilst most sites reported carbonised remains, 13 only had data from impressions in ceramics and/or plaster/daub, and waterlogged plant remains were retrieved from La Draga and La Marmotta (Table 3). In order to overcome such disparities, findings were reduced to presence/absence of taxa by site/phase as the common means of quantification. Plant parts (e.g grain or chaff), archaeological contexts and quantities (absolute or relative) were not considered, such that a rise in a ubiquity score does not necessarily translate to an increase in the absolute number of a taxon. There are a growing number of successful uses of such parsimonious data (ubiquity by site/phase) to explore spatio-temporal patterns in the distribution of taxa across large geographical areas (e.g. Colledge *et al*., 2004, 2005; Coward *et al*., 2008; Gaastra *et al*., 2019).

Patterns in the binary dataset were illustrated through ubiquity scores of taxa by phase (Figure 4), Simpson’s diversity index (Figure 7) and correspondence analysis (Figure 8). The latter two were undertaken in R software (R Development Core Team 2008). Simpson’s index (S) is a measure of diversity more commonly used in ecology, that can be performed on presence/absence data

(Gardener, 2014: 151-159). As such, the higher the value of S, the less diverse the assemblage. As this behaviour is somewhat counter-intuitive, it is frequent to use a value of 1-S, often referred to as Simpson's index of diversity (D), so that the greater the value, the higher the sample diversity. This specific index was calculated using the diversity function in the R package vegan (Oksanen *et al.,* 2019), and then all values plotted as boxplots based upon their phase attribution (using the R package ggplot2: Wickham, 2016). Correspondence analysis is used to search for patterns in complex data, by ordering units of analyses according to their similarities. This multivariate statistical method of ordination is increasingly used to analyse archaeobotanical assemblages and is suitable for presence/absence data (Smith, 2014). Here it is used to compare variations in the presence of taxa by phase and site type (R package 'ca'; Nenadić and Greenacre, 2007).

Whilst some crops may not have been used at particular sites, their absence from archaeobotanical records may in fact result from the effects of preservation, excavation, sampling strategies and sample treatment procedures. For example, some reports note that bulk samples were sieved or floated using large mesh sizes (1mm or even 2mm). Whilst this approach undoubtedly leads to the loss of small seeds, such as those of poppy and possibly flax, we feel that cereal grains and most of the cultivated pulses would have been retained. The considerable range in the number of samples taken from sites may also explain the variation in the number of represented crops per site. To assess the effects of some potential biases on the patterns of crop distributions, three additional analyses were performed. Our use of the correlation function tests whether crop diversity is correlated to sample quantities by plotting the 57 sites with known quantities of samples against their species richness (Figure 2). Logarithmic values were used to account for the large range of sample numbers (from 1 to 1281 from site 44; following Lyman, 2015). Similarly, the recovery of plant impressions without bulk soil sampling (representing 23% (n=9) of Phase 2 sites) can create biases against particular crops. Cereals added to the temper of pottery or daub may represent a very specific and selective range of species, and casts of pulses, not to mention other seeds, fruit stones and nuts, are rarely identified (*cf.* Fuller *et al*., 2014: 199-205; McClatchie and Fuller, 2014). Site function is the third condition we assess. Cave sites (including rockshelters) are sometimes described as temporary or seasonal settlements (e.g. Bonsall *et al*., 2015; Reed, 2015: 615; Martín *et al*., 2010) where crop processing and consumption may have been less prominent/diverse. As 34% (n=41) of the samples originate from cave sites, we tested for the effect of site function on crop diversity (Figures 3 and 8).

No.	**Site**	**Type**	**Phase**	**Preservation status**	**Source** (including C14 dates)
Greece and Crete					
1	Achilleion	Tell	1	Charred	Ivanova *et al*. 2018; Renfrew 1979; Valamoti & Kotsakis 2007
2	Argissa Magoula	Tell	1	Charred	Renfrew 1979; Valamoti & Kotsakis 2007
3	Franchti	Cave	1	Charred	Renfrew 1979; Valamoti & Kotsakis 2007
4	Gediki	Tell	1	Charred	Ivanova *et al*. 2018; Renfrew 1979; Valamoti & Kotsakis 2007
5	Giannitsa B	Open-air	1	Charred	Ivanova *et al*. 2018; Valamoti & Kotsakis 2007
6	Knossos	Tell	1	Charred	Colledge 2016; Renfrew 1979; Valamoti & Kotsakis 2007
7	Mavropigi-Fyllotsairi	Open-air	1	Charred	Valamoti 2011
8	Nea Nikomedeia	Tell	1	Charred	Ivanova *et al*. 2018; Renfrew 1979; Valamoti & Kotsakis 2007

No.	**Site**	**Type**	**Phase**	**Preservation status**	**Source** (including C14 dates)
9	Otzaki Magoula	Tell	1	Charred	Ivanova *et al*. 2018; Valamoti & Kotsakis 2007
10	Podromos	Tell	1	Charred	Ivanova *et al*. 2018; Valamoti & Kotsakis 2007
11	Servia-Varytimides	Open-air	1	Charred	Ivanova *et al*. 2018
12	Sesklo	Tell	1	Charred	Colledge 2016; Ivanova *et al*. 2018; Renfrew 1979; Valamoti & Kotsakis 2007
13	Soufli	Tell	1	Charred	Colledge 2016; Ivanova *et al*. 2018; Renfrew 1979; Valamoti & Kotsakis 2007
14	Toumba Balomenou	Tell	1	Charred	Sarpaki 1995; Valamoti & Kotsakis 2007
Croatia (Dalmatia)					
15	Crno Vrilo	Open-air	2	Charred	Marijanović 2009
16	Kargadur-Ližnjan	Open-air	2	Charred	Komšo 2005
17	Krćina pećina	Cave	2	Impressions	Müller 1994
18	Pokrovnic	Open-air	2	Charred	Reed & Colledge 2016
19	Tinj-Podlivade	Open-air	2	Charred	Huntley 1996
Sardinia, South and Central Italy					
20	Acconia, area C	Open-air	2	Charred	Costantini and Stancanelli 1994
21	Canosa	Open-air	2	Charred	Fiorentino *et al*. 2013
22	Coppa Nevigata	Open-air	2	Charred	Fiorentino *et al*. 2013; Sargent 1987
23	Defensola A	Open-air	2	Charred	Fiorentino *et al*. 2013
24	Filiestru	Cave	2	Charred	Ucchesu *et al*. 2017
25	Foggia, Ex-ippodromo	Open-air	2	Charred	D'Oronzo and Fiorentino 2006; Fiorentino *et al*. 2013
26	à Foggia, Villa Communale	Open-air	2	Charred	Nisbet 1982; Fiorentino *et al*. 2013
27	Fontanelle	Open-air	2	Impressions	Coppola and Costantini 1987; Fiorentino *et al*. 2013
28	Grotta delle Mura	Cave	2	Charred	Fiorentino *et al*. 2013
29	à Grotta dell'Uzzo	Cave	2	Charred	Costantini and Stancanelli 1994; Shennan and Steel 2000
30	Grotta Sant'Angelo	Cave	2	Impressions	Costantini and Stancanelli 1994
31	Lagnano da Piede	Open-air	2	Charred	Jones 1987; Fiorentino *et al*. 2013
32	Lago di Rendina, Sito n.3	Open-air	2	Charred	Costantini and Stancanelli 1994
33	La Marmotta	Open-air	2	Charred and waterlogged	Rottoli 1993
34	Le Macchie	Open-air	2	Impressions	Costantini and Stancanelli 1994
35	Masseria Candelaro	Open-air	2	Charred	Costantini and Stancanelli 1994; Fiorentino *et al*. 2013
36	Masseria Valente	Open-air	2	Charred	Costantini and Stancanelli 1994; Fiorentino *et al*. 2013

No.	Site	Type	Phase	Preservation status	**Source** (including C14 dates)
37	Monte Aquilone	Open-air	2	Impressions	Evett and Renfrew 1971
38	Monte Calvello	Open-air	2	Charred	D’Oronzo *et al*. 2008
39	Monte San Vincenzo	Open-air	2	Charred	D’Oronzo *et al*. 2008
40	Palese	Open-air	2	Impressions	Evett and Renfrew 1971
41	Pulo di Molfetta	Open-air	2	Charred	Fiorentino *et al*. 2013; Primavera and Fiorentino 2011
42	Rendina	Open-air	2	Charred	Costantini and Stancanelli 1994; Shennan and Steel 2000
43	Ripa Tetta	Open-air	2	Charred	Costantini and Stancanelli 1994; Fiorentino *et al*. 2013
44	Scamuso	Open-air	2	Charred	Costantini and Stancanelli 1994; Fiorentino *et al*. 2013
45	Terragne	Open-air	2	Charred	Fiorentino *et al*. 2013; Mercuri *et al*. 2015
46	Títolo	Open-air	2	Charred	Fiorentino *et al*. 2013
47	Torre Canne	Open-air	2	Impressions	Coppola and Costantini 1987; Evett and Renfrew 1971; Fiorentino *et al*. 2013
48	Torre Sabea	Open-air	2	Charred	Costantini and Lentini 2003; Fiorentino *et al*. 2013; Marinval 2003a, 2003b
49	à Villagio Leopardi	Open-air	2	Impressions	Evett and Renfrew 1971; Costantini and Stancanelli 1994
North Italy					
50	Arene Candide	Cave	2	Impressions	Arroba *et al*., 2017; Pearce 2013; Rottoli and Castiglioni 2009
51	Bazzarola	Open-air	3	Charred	Carra 2012; Carra and Ricciardi 2007
52	Cava Barbieri	Open-air	2	Charred	Costantini and Stancanelli 1994
53	Cecima	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
54	Chiozza	Open-air	3	Impressions	Evett and Renfrew 1971; Pearce 2013
55	à Fagninola	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
56	Lugo di Grezzana	Open-air	3	Charred	Pearce 2013; Rottoli *et al*. 2015
57	Lugo di Romagna	Open-air	3	Charred	Pearce 2013; Rottoli in press; Rottoli and Pessina, 2007
58	Ostiano-Dugali Alti	Open-air	3	Impression	Nisbet 1995; Pearce 2013
59	Pavia di Udine	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
60	Piancada	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
61	Pizzo di Bodio	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
62	Ponte Ghiara	Open-air	3	Charred	Carra 2012
63	à Rivaltella Cà Romensini	Open-air	3	Charred	Carra 2012; Marziani and Tacchini 1996

No.	Site	Type	Phase	Preservation status	Source (including C14 dates)
64	Sammardenchia	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
65	Valler	Open-air	3	Charred	Pearce 2013; Rottoli and Castiglioni 2009
66	Vhò di Piadena-Campo Ceresole	Open-air	3	Charred	Castelletti and Maspero 1992; Pearce 2013
France					
67	Abri Roc Troué	Cave	4	Charred	Erroux 1992
68	Aspre del Paradís	Open-air	4	Charred	Bouby *et al*. 2016; Manen *et al*. 2001
69	Balma de l'Abeurador	Cave	3	Charred	Vaquer and Ruas 2009
70	Baume Bourbon	Cave	4	Charred	Erroux 1976
71	Baume d'Oulen	Cave	3	Charred	Erroux and Marinval unpublished; Bouby *et al*. 2016
72	Cova de l'Esperit	Cave	3	Charred	Marinval 1988
73	Font Juvénal	Cave	4	Charred	Marinval 1988
74	Font aux-Pigeons	Cave	4	Impressions	Marinval 1988
75	Fontbrégoua	Cave	4	Charred	Savard 2000
76	Grotte de l'Aigle	Cave	3	Charred	Erroux 1979
77	Grotte du Gardon	Cave	3	Charred	Bouby 2009
78	Grotte du Taï	Cave	3	Charred	Bouby *et al*. 2018; Manen *et al*. 2018a
79	Grotte Gazel	Cave	3	Charred	Bouby *et al*. 2016; Manen *et al*. 2018a
80	Grotte Saint Marcel	Cave	4	Charred	Erroux 1988
81	La Resclauza	Open-air	4	Impressions	Marinval unpublished; Bouby *et al*. 2016
82	Le Valladas	Open-air	4	Charred	Beeching *et al*. 2000; Martin unpublished
83	Mas de Vignoles X	Open-air	4	Charred	Bouby and Figueiral 2014
84	Mas Neuf	Open-air	4	Charred	Bouby and Figueiral 2014
85	Peiro Signado	Open-air	2	Charred	Marinval unpublished; Bouby *et al*. 2016; Manen *et al*. 2018a
86	Pendimoun	Cave	3	Charred	Binder *et al*. 1993
87	Périphérique Nord-Lyon	Open-air	4	Charred	Vital *et al*. 2007
88	Pont de Roque Haute	Open-air	2	Charred	Marinval 2007
89	Roc de Dourgne	Cave	4	Charred	Marinval 1993
Switzerland					
90	Tourbillon	Open-air	4	Charred	Martin 2015
91	La Gillière	Open-air	4	Charred	Martin 2015
92	La Planta	Open-air	4	Charred	Martin 2015
Spain					
93	Abric de la Falguera	Cave	3	Charred	Pérez-Jordà 2013
94	C/Reina Amàlia 31-33	Open-air	4	Charred	Antolín 2016
95	Can Sadurní	Cave	3	Charred	Antolín and Buxó 2011b, Antolín and

No.	Site	Type	Phase	Preservation status	**Source** (including C14 dates)
96	Can Sadurní	Cave	4	Charred	Schäfer, Submitted; Edo *et al*. 2011
97	Caserna de Sant Pau	Open-air	3	Charred	Buxó and Canal 2008
98	Coro Trasito	Cave	3	Charred	Antolín *et al*. 2018; Clemente *et al*. 2016
99	Coro Trasito	Cave	4	Charred	
100	Cova de l'Or	Cave	3	Charred	Pérez-Jordà 2013
101	Cova de les Cendres	Cave	3	Charred	Buxó 1997
102	Cova de les Cendres	Cave	4	Charred	
103	Cova de Sant Llorenç	Cave	3	Charred	Antolín 2016
104	Cova de Sant Llorenç	Cave	4	Charred	
105	Cova del Sardo	Cave	4	Charred	Antolín 2016
106	Cueva Bajondillo (Torremolino)	Cave	3	Charred	Peña-Chocarro and Zapata 2010; Pérez-Jordà *et al*. 2017
107	Cueva de los Mármoles	Cave	3	Charred	Peña-Chocarro *et al*. 2018
108	Cueva de los Murciélagos de Zuheros	Cave	3	Charred	Peña-Chocarro 1999
109	Cueva del Toro (IV)	Cave	3	Charred	Buxó 2004
110	Cueva de Nerja	Cave	3	Charred	Aura Tortosa 2005; Pérez-Jordà *et al*. 2017
111	Font del Ros	Open-air	3	Charred	Pallarès *et al*. 1997
112	Hostal Guadalupe	Cave	3	Charred	Peña-Chocarro *et al*. 2018
113	La Draga	Open-air	3	Charred	Antolín 2016; Antolín and Buxó 2011a; Buxó *et al*. 2000; Berrocal *et al*. In press
114	La Higuera	Open-air	3	Charred	Espejo Herreras *et al*. 2013
115	Los Arcos	Open-air	3	Charred	Peña-Chocarro *et al*. 2005
116	Los Castillejos	Open-air	3	Charred	Rovira 2007
117	Los Castillejos	Open-air	4	Charred	
118	Mas d'Is	Open-air	2	Charred	Pérez-Jordà 2005, 2013
119	Mas Cremat (Cingle del)	Cave	3	Charred	Pérez-Jordà 2010
120	Plansallosa	Open-air	4	Charred	Bosch *et al*., 1998
121	Roca Chica	Cave	3	Charred	Peña-Chocarro *et al*. 2018
122	Tossal de les Basses	Open-air	4	Charred	Pérez-Jordà 2013

Table 3: Summary information on the sites included in the study

Results

Evaluating the patterns

The analyses performed on sample numbers, preservation type and site type suggest that patterns of crop distributions are not significantly biased by these external conditions. Figure 2 shows a weak positive correlation between the number of samples and the number of taxa per site (Spearman's rho: 0.458, $p<0.05$), and that this association only accounts for a very small fraction of the total variance (R^2: 0.1467, $p<0.05$). Therefore the number of samples cannot be described as a significant bias against the variable presence of crop taxa by site. Neither was the diversity by phase influenced by sites with records of crops solely from impressions. For instance, the majority of sites with impressions comes from phase 2 (9 out of 13 sites), though this sample size remains limited when compared to the number of sites with remains obtained through flotation for the same period (n=31). Simpson's index by phase was also calculated without records of impression (not shown here) but the results were almost identical to Figure 7, demonstrating that the diversity of crop packages is not strongly biased by the inclusion of impressions.

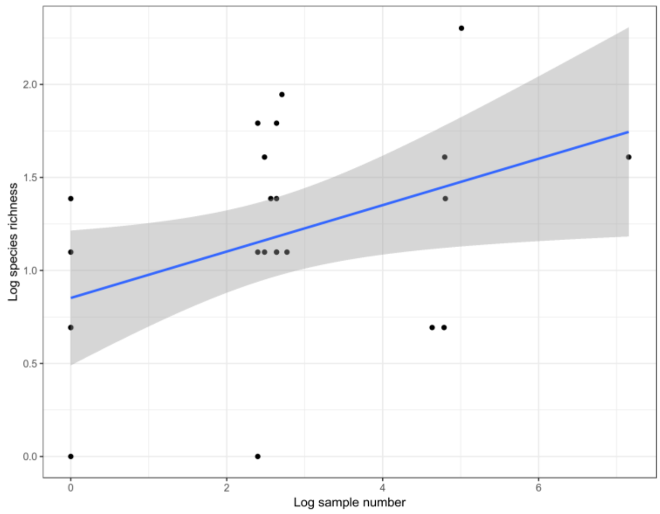


Figure 2: Graphical representation of the relationship between sample numbers and the species richness per site (the number of species included in this study, not their absolute quantities), for the 57 sites with known sample numbers.

The function of sites and possible variations in the use of crops may have influenced distribution patterns. A third of all sites were caves or rockshelters, the majority of which were from Phases 3 and 4 (50%, n=34). However, Figure 3 demonstrates that caves/rockshelters did not, on average, contain fewer taxa or indeed a specific range of taxa compared to other site types. None of the site types form a distinct cluster in the correspondence analyses, which indicates that the distribution of crop taxa is not simply influenced by site type.

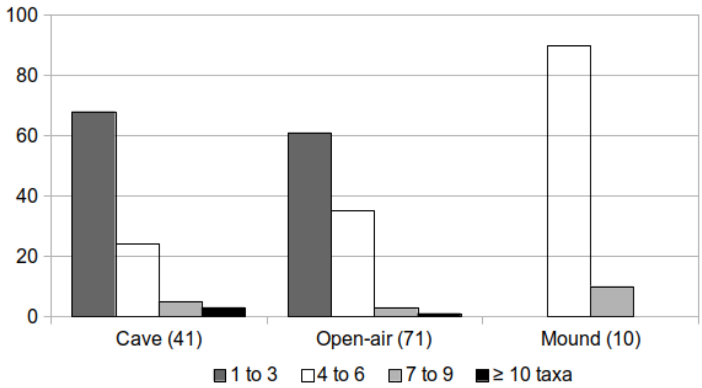


Figure 3: Ubiquity values for the number of crop taxa found at the three types of sites

Frequency charts and crop distribution

The 122 sites/phases are not evenly distributed between the three phases. Phases 2 and 3 have a similar amount of sites (n=40 and 43 respectively), but Phase 1 only has 14 and the last Phase 25. Discrepancies are also visible in their geographic distributions, with an absence of sites form coastal areas of Albania, Montenegro, western Italy and parts of southern Spain.

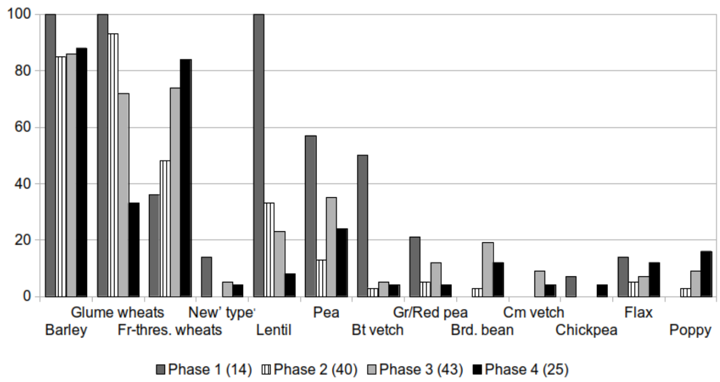


Figure 4: Ubiquity values by phase for the crops included in the study

Barley, emmer, einkorn, free-threshing wheat, lentil, pea, grass/red pea, bitter vetch and flax are present throughout the investigated area. Broad bean and poppy are not recorded from Greek sites, and common vetch is only present in North Italy (sites 59, 60 and 64) and Spain (sites 96 and 108). Chickpea has an unusual distribution, being only present at one of the earliest (site 10) and one of the latest (site 96) sites. The 'new' glume wheat is currently recorded from five sites. It is present in Greece (sites 5 and 7), northern Italy (sites 62 and 111) and Spain (site 96).

The glume wheats emmer and einkorn are ubiquitous in Greece but their frequencies are seen to drop with the westward expansion of farming. They are only recorded from a third of sites in France and Spain during the final Phase 4. The almost exact opposite pattern is evident for free-threshing wheat, which is present in 36% (n=5) of Greek sites (Phase 1) but 84% (n=21) of French and Spanish Phase 4 sites. It is during *c*.5500-5000 cal. BC in northern Italy, France and Spain when both hulled and naked wheats appear to have been as frequent.

Although barley is present at almost every site, its high frequency may be misleading compared to those of the wheat types. Unlike the latter it is not split into its hulled and naked forms, which may also show bigger spatio-temporal variations. Indeed, where possible, records of naked and hulled barley were accounted for (Figure 6), though results must be seen as preliminary until further identifications can be made on the finds of indeterminate barley that dominate the records. Nevertheless, the gradual decline in hulled barley and incline in naked barley between Phases 1 to 4 is comparable to the same trajectory evidenced in the wheats. Together the records suggest that hulled cereals were the main crops during the first two phases, after which an increasing preference for naked cereals is apparent.

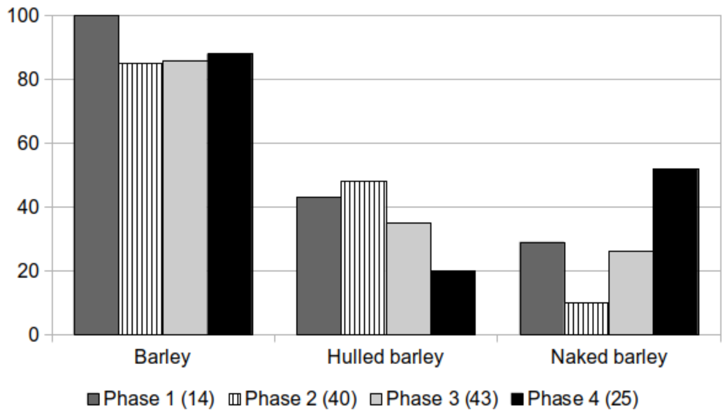


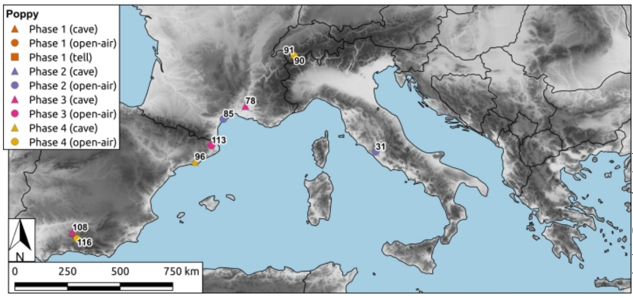
Figure 5: Ubiquity values by phase for hulled and naked barley

Lentil is present in all the Greek sites, and pea and bitter vetch in at least half of them. A sharp decline in frequencies is seen over Dalmatia and southern Italy, particularly for lentil (Phase 2).

Bitter vetch then remains rare throughout the Mediterranean whilst the frequency of lentil continues to drop, whilst that of pea shows a slight increase. Although lentil is ubiquitous at the earliest sites in Greece, by the time the westward expansion of farming has reached northern Italy, France and Spain pea is more frequent.

The ubiquity scores for grass/red pea are not as high as those for pea but follow a similar pattern. The main difference is that grass/red pea is rarest from the latest sites. Broad bean and common vetch have relatively high frequencies during Phase 3. Indeed, broad bean is the third most frequent pulse in northern Italy, France and Spain during the first half of the sixth millennium BC. Although frequencies of broad bean and common vetch drop thereafter, they are less rare at the latest sites than at earlier sites from Dalmatia and southern Italy (Phase 2).

Flax is present in low frequencies throughout the westward expansion of farming, though it is rarest from sites dating to the sixth millennium BC (Phases 2 and 3). Although relatively rare, poppy is the only crop to show a continuous increase in frequency from Phase 2 onwards. It is present across the western Mediterranean where it is recorded from central Italy (site 33), France (sites 78 and 85), Switzerland (sites 90 and 91) and up to Andalusia in Spain (sites 96, 108, 116 and 117). It is worth stressing that both these taxa are likely to be under-represented, not only due to their propensity to burst when heated (Märkle and Rösch 2008) but also to their small size. The use of 1-2mm sieving/floating meshes for the recovery of plant remains creates a bias against small seeded crops, as well as cereal chaff and wild plant seeds.



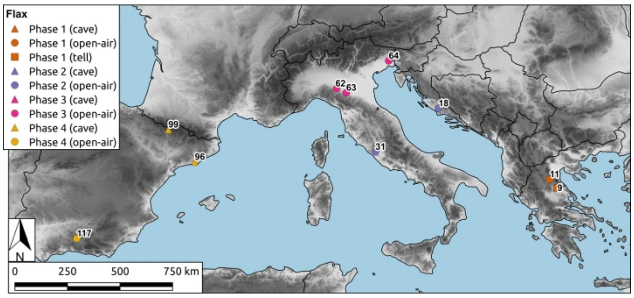


Figure 6: Location of sites with poppy (left) and flax (right). Distribution maps for all the other crops can be found in the electronic supplementary information

Simpson's diversity index and correspondence analyses

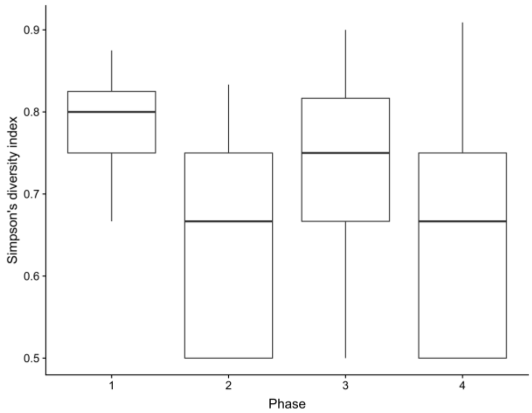


Figure 7: Simpson's diversity index by phase

The highest diversity is seen in Phase 1, in which taxa are most evenly distributed along axes 1 and 2 of Figure 8. All Phase 1 sites contain glume wheats, barley and lentil, and about half have pea and bitter vetch. Free-threshing wheat is less common (found in 36% of sites, n=5), as is grass/red pea (found in 21% of sites, n=3). Flax is found at Servia and Otzaki Magoula, the latter being the only site with chickpea. The most significant drop in diversity is seen between Phases 1 and 2. Phase 2 sites plot closer to the core Neolithic ‘package’ of glume wheats, barley, lentil and pea, with the exception of a few outliers that contain rare finds of flax (sites 18 and 33), bitter vetch (site 38), grass/red pea (sites 18 and 29) and two new crops: broad bean (site 42) and opium poppy from La Marmotta on the West coast of Italy (site 33) (Figures 6 and 8). Barley and glume wheats continue to be the most frequent crops, though the presence of free-threshing wheat increases by 12%. There is a significant drop in the ubiquity scores of lentil (33%, n=13) and pea (13%, n=5) (Figure 4). The diversity increases into Phase 3, with values of Simpson’s index of diversity spanning a large range. Indeed, the sites of Phase 3 are the most evenly distributed across the CA space, showing not only the highest range in diversity but also the largest geographical coverage (from North Italy to Andalusia). The high ubiquity of barley is maintained, but free-threshing wheats are now as common as hulled wheats (74%, n=32 and 72%, n=31 respectively). Whereas pea and grass/red pea are more frequent than in Phase 2, the drop in the frequency of lentil continues and it is now found in fewer sites than pea. Common vetch is found for the first time in Phase 3 (sites 59, 60, 64, 96 and 108), and broad bean has the highest ubiquity score of all phases (19%, n=8). Flax and opium poppy are slightly more common than in the previous phase. Phase 4 has the same diversity index and range of values as Phase 2, although the species richness and abundance differ. Barley is still very common but the high ratio of hulled to free-threshing wheats evident in the first two phases is reversed. Free-threshing wheat is now more frequent, as can be seen by the greater number of Phase 4 sites plotting in the top left quadrant of Figure 8. All the pulses are present, although their ubiquity scores are reduced compared to Phase 3, particularly for lentils which falls by 15%. The exception constitutes the only other find of chickpea from the research area (site 96). The frequencies of flax and opium poppy are slightly higher than in Phase 3, and higher than those of lentil, grass/red pea and both vetches.

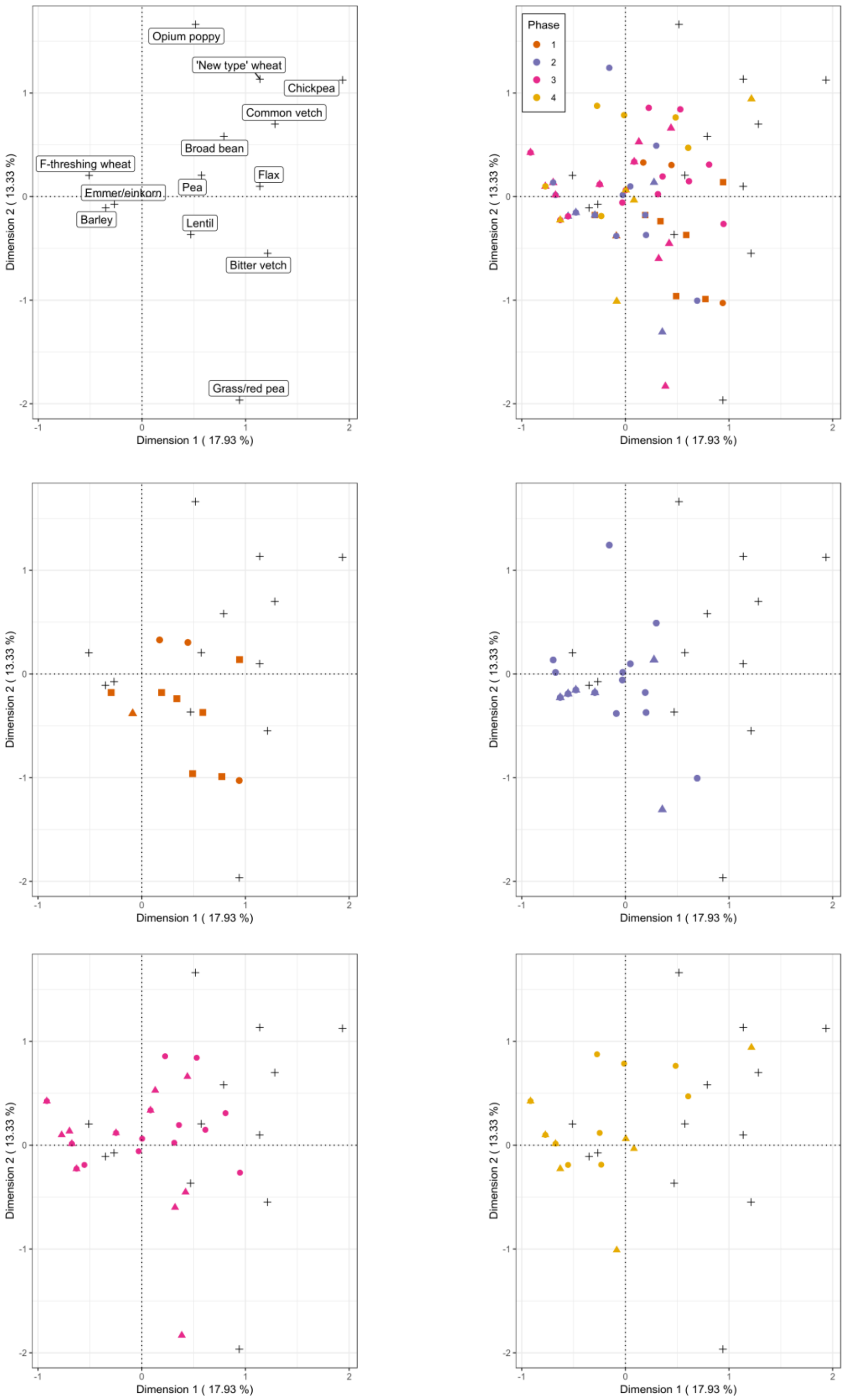


Figure 8: Correspondence analyses of crops by phase. Crop labels and individual phases are presented separately for ease of viewing

Discussion

Testing the patterns

The crop distribution patterns evidenced during the initial neolithisation of the Adriatic and north-western Mediterranean show spatio-temporal variations in both the range and the ubiquity of crops. In order to test the significance of these patterns, and before the latter can be discussed, phenomena which may have altered the true distribution of crop taxa were tested for. Figure 2 indicates that the range of crop taxa by site is not strongly influenced by the number of samples processed. Sample numbers were only available for 47% of sites, and volumes were rarely specified. Sample volumes and other details such as the description and number of features/contexts would have made for a more accurate comparison between sites. It is worth stressing that this result does not affirm that comprehensive sampling strategies are not more likely to obtain representative assemblages of archaeobotanical remains. Instead, it reassures that the variable presence (not absolute counts) of the twelve crops of interest to this study does not appear to be a direct outcome of variable sample numbers. Similarly, the inclusion of sites whose records of plant remains were obtained solely from impressions within ceramic, plaster and/or daub, does not negatively affect the diversity of crop packages by phase. The range of crops utilised at any particular site is likely to be under-represented in the record of impressions, as pulses and seeds from oil and fibre crops are seldom recovered. However, at the scale of our analyses, the inclusion of impressions does not appear to bias against non-cereal crops, and allows for a more complete record of cereal finds. Results from the analyses performed to evaluate the obtained patterns of crop distribution are specific to the scale of our observations and our research agenda. They were limited by the available data, and we take this opportunity to urge archaeobotanists to include in their reports and publications as many details from excavations, sample strategies, recoveries and processing as possible. These factors can severely bias the plant record, and lead to inappropriate analyses with erroneous interpretations.

Overall cave sites did not contain a restricted range of crops. The number of taxa found in caves/rockshelters is comparable to that from open-air settlements (Figure 3), suggesting that the same diet of cultivated plants is represented across both site types (*cf*. Antolín *et al*., 2018). Although aspects of cultivation and crop processing cannot be addressed here, the presence of charred seeds in caves suggests crops were not (uniquely) transported as flour or fully cooked foods. Raw crops may have been an easier and more durable product to transport if caves were only seasonally or occasionally used. Conversely, large quantities of cereal remains could be an indication of more perennial occupations and the cultivation of surrounding soils (Antolín *et al*., 2018; Martin *et al*., In press).

The range of taxa found at the Greek tell sites is very consistent. The rapid build-up of tell sites and the dense accumulation of waste tend to lead to better preservation of charred botanical remains (Bogaard and Halstead, 2015: 391; Valamoti, 2005). These hypotheses are supported by our results which show that no fewer than four crop taxa were frequently recovered from the tell sites. Only one site contained more than six crops: Otzaki Magoula with the only find of chickpea as well as flax (present at only two Greek sites). Opium poppy, broad bean and common vetch were not found at any of the Greek sites. The absence of the latter two crops is curious, considering they were present at earlier sites in SW Asia (Caracuta *et al*., 2016; 2017; Zohary *et al*., 2012: 89-92).

Taxa frequencies and crop distributions

A spatio-temporal shift is evident from the preference of emmer, einkorn and hulled barley to free-threshing wheat and naked barley. Records of naked barley are currently unsatisfactory although our results suggest it became more common towards the end of the Early Neolithic. At some sites in Andalusia and the region of Valencia (Spain) it was already an important crop during Phase 3 (sites 97, 108, 109, 116 and 121) (Pérez-Jordà *et al*., 2017). Further East in Catalonia its cultivation was not prominent until the Middle Neolithic (*c*.4500-3200 cal BC) (Antolín *et al*., 2015). Free-threshing wheat is initially thought to have been a minor crop, or a weed of glume wheats during the first spread of farming through the Balkans and into southern Italy and central Europe (Bogaard, 2011: 38; Filipović & Obradović, 2013; Reed, 2015; Rottoli and Pessina, 2007; Valamoti and Kotsakis, 2007). In northern Italy, during our Phase 3, free-threshing wheats become as frequent as the glume ones. However, emmer and einkorn are still found in greater quantities and it seems that free-threshing wheat remained insignificant (Rottoli and Castiglioni, 2009: 95-97). It is only in the western Mediterranean where free-threshing wheat is found in greater frequencies and quantities than the glume wheats (Peña-Chocarro *et al*., 2018; Pérez-Jordà *et al*., 2017). Glume wheats were not completely abandoned but persisted at some sites (Antolín *et al*., 2015; Zapata *et al*., 2004). Both tetraploid (*Triticum durum/turgidum*) and hexaploid (*T. aestivum*) free-threshing species have been found, though the former is thought to have been the main wheat of the Early Neolithic along the Iberian coast (Peña-Chocarro *et al*., 2018).

Hulled cereals are more labour intensive but can grow in poor soils and are more resistant to pests and diseases during growth as well as storage (Nesbitt and Samuel, 1996). Additionally, emmer and einkorn straw are known to have been important products, being used as fuel, for thatching, bedding, basketry and in numerous other ways (Peña-Chocarro and Zapata, 2014; Peña-Chocarro *et al*., 2009). Free-threshing cereals are easier to process since the grains are not firmly encased within their glumes. Pioneer farming communities tended to be small (e.g. Jover Maestre *et al*., 2019; Porčić, 2018), and lack of labour may have led to a preference in cereals that required less time and energy to process. Although little information is available for the western Mediterranean, entomological analyses suggest that cereal pests existed during the Early Neolithic in the Balkans and central Europe, but then seem to disappear quite early in the neolithisation process (Panagiotakopulu and Buckland, 2018). Contrary to the latitudinal gradient experienced during the inland spread into Europe, the neolithisation of the Mediterranean would not have been subject to significant climatic and seasonal variations. Consequently, and as emmer, einkorn and tetraploid free-threshing wheats are all suited to a Mediterranean climate, farmers may have been able to focus on crops that were better suited to their labour capacities. A reduced threat of pests, along with possible adaptations in storage facilities (Prat *et al*., Submitted), may also have encouraged a focus on free-threshing wheat. The rise in naked cereals in the western Mediterranean pre-dates evidence for larger settlements and woodland clearings (Badal García *et al*., 1994; López Sáez *et al*., 2011; Jalut *et al*., 2000), suggesting that the change in focus was not caused by a possible shift from an intensive agricultural system to an extensive one based on a restricted range of cultivars. This is also suggested by multi-proxy site-scale analyses such as at the lake dwelling site of La Draga, where naked wheat is one of the main crops (Antolín *et al*., 2014; Revelles *et al*., 2014). Nevertheless, naked cereals, together with hulled barley, may have facilitated large-scale cultivation and the rise of settlement densities during the Bronze and Iron Ages, as they are easier/faster to process and store for later re-distribution (e.g. Bouby, 2014; Alagich *et al.*, 2018; Alonso, 1999; Alonso and Bouby, 2017).

Lentil and pea were part of the original suite of cultivated crops and were the two most common pulses in the Neolithic diet of southern Europe and SW Asia (Zohary *et al*., 2012: 77-87). They are found during all four phases, although they become less frequent during the westward migration of farming, particularly lentil. Modern cultivars of lentil are more tolerant of drought and heat, and have a slightly longer growing season than peas (Andrews and McKenzie, 2007; Ecocrop). Summer and particularly winter average temperatures during the Early Neolithic of the research area are calculated to have been one to two degrees lower than today's (Mauri *et al*., 2015: Figs 3 and 4), perhaps creating climatic conditions which were more suitable to pea. The most important stage in a crop's development is its flowering time, and in pulses flowering is sensitive to both temperature (accumulated degree-days) and photoperiod (light duration, quality and radiant energy) (Craufurd and Wheeler, 2009; Iannucci *et al*., 2008; Weller and Ortega, 2015). Modern pea and lentil varieties have the shortest growing seasons (pea more so than lentil whose cultivation area is more restricted; Cubero, 1981: Fig.2), suggesting that their cultivation over other pulses may have been determined by shorter growing seasons (they would still have had time to fruit if flowering had been delayed by colder temperatures and/or shorter light hours). Nevertheless, it is surprising that some pulses (e.g. broad bean) could be grown in southern Italy (site 42) but not in Dalmatia or Greece, and it seems that climatic adaptations were not the only parameters to determine the selection of crops. Historically, vetches and grass pea are known to have been grown for fodder (e.g. Bouby and Léa, 2006; Jones and Halstead, 1995: 103; Zapata *et al*., 2004: 297). Despite their high protein content, the seeds are toxic to humans and cannot be consumed without lengthy pre-treatments (Bouby and Léa, 2006: 978). Their under-representation in the archaeobotanical record may be related to their secondary economic role (as fodder) or to their lower importance as a food resource. Similarly, the patchy appearance of chickpea may be due to its specific use as an animal food (Antolín and Schäfer, submitted).

Findings of the 'new' glume wheat are becoming more common as the taxa is better represented across research laboratories. Indeed, it's overall low presence and complete absence from Dalmatia and southern Italy (Phase 2) may be more an artefact of developments in the discipline than real prehistoric crop use, as 60% of Phase 2 sites were published before the formal identification of the 'new type' (Jones *et al*., 2000; Kohler-Schneider, 2003). At present, our results suggest that the 'new type' was probably present across the research area though rare in both frequency and absolute quantities.

Oil plants are equally poorly represented in the studied area, which is most likely due to their difficult preservation by charring (particularly poppy which can be abundant in waterlogged deposits, such as at La Draga or La Marmotta) (Märkle and Rösch 2008; Wilson, 1984). Such a bias in the representation of charred remains of oil plants has been repeatedly observed in the Neolithic lakeshore settlements found in the Alpine foreland (Jacomet *et al*., 1989). Despite this fact, there is a significant difference between the distribution of flax and opium poppy in our maps. While flax is present in sites located all across the studied region (except southern Italy), poppy is only found in central Italy and the Western Mediterranean region. There are only very scanty references to the presence of poppy in the Near East (Kislev *et al*., 2004; Rössner *et al*., 2018), leaving the question open for a domestication of this crop in the western Mediterranean region (Salavert *et al*., 2018). This phenomenon could have started in central Italy and quickly spread westwards with the first farming settlements found in the NW Mediterranean region. From there it could have spread northwards (Salavert, 2010). Flax was virtually absent from the carpological record in the Iberian Peninsula until relatively recently (Stika, 2005; Rovira, 2007), but it is more commonly found in recent studies thus showing a possible methodological bias that may also account for its absence in southern Italy. Both crops would have been demanding for early farmers and they may have been grown at a very small scale like the small plots of poppy that have traditionally been grown in the house gardens of South Tyrol (Schilperoord, 2017).

Exploring diversity

When a fraction of a farming population leaves to colonise new areas a drop in the diversity of their crop package is expected (Conolly *et al*., 2008; Drost and Vander Linden, 2018; Pérez-Lozada and Fort, 2011). The loss of taxa through founder effects such as neutral drift and homophily is unpredictable, as is the time required for these taxa to be re-introduced. The drop in the diversity of crop packages during the first westward maritime spread mimics the same phenomena seen along the inland route into Europe (Colledge and Conolly, 2007; Coward *et al*., 2008; McClatchie *et al*., 2014), where impacts of founder effects are hard to separate from those of rising latitudes and climate change. Conversely, the latter two conditions are less likely to have resulted in the abandonment of particular crops within the Adriatic and Mediterranean zone, suggesting that a drop in diversity, observed in reducing values of Simpson's index, particularly in Phase 2, is more likely an outcome of the process of migration. Changes in diversity indices between Phase 1 and 4 are testimony to the arrhythmic nature of the migration (Guilaine, 2001), which included pauses for establishing settlements and perhaps building networks with other communities across the Mediterranean or further inland. For example, the presence of common vetch in Phase 3 may point to destinations beyond Greece as the pulse is not known within the Adriatic or Aegean at that time (Marinova and Valamoti 2014; de Vareilles, Unpublished). Similarly, broad bean is present in Phase 2 but currently absent from the Greek Neolithic (Marinova and Valamoti, 2014). The signal is further complicated by the increased rate of expansion into the western Mediterranean, and the possible inclusion of fifth millennium sites into Phase 3 (see methodology). As such, we may not have captured the very first migration out of southern Italy, but show the effects of regular, multi-directional movements across the research area. The drop in Simpson's diversity index in Phase 4 appears to illustrates the increased focus on a narrower range of cereals in the western Mediterranean.

Conclusion

Changes in both the frequency of taxa and in the diversity of crop packages are evident during the first maritime neolithisation of the Adriatic and north-western Mediterranean. The core group of barley, wheats, lentil and pea are found throughout, though significant changes in the frequency of hulled to naked cereals, and of lentil to pea occurred during the second half of the sixth millennium. Other pulses, such as bitter vetch, grass/red pea and chickpea, appear to have been almost abandoned, whilst some were introduced at later dates. Poppy seems to have held an important role within the western Mediterranean agricultural system, although the precise locale of its domestication currently remains enigmatic. Explaining such diversity is complicated, not least because of the numerous natural and cultural factors that would have shaped the agrarian model. Nevertheless, we suggest that climatic and environmental changes had minor consequences, and that crop packages were more influenced by founder effects and the nature of maritime trajectories. Our results support other archaeological evidence in depicting regional details and multi-directional maritime trajectories, within a broader westward maritime expansion of the Neolithic.

Collation of the dataset for this article has revealed large geographical gaps where further research is clearly needed. Additionally, there is a large disparity between different countries in the levels of published details. Presence/absence data is informative, and we concur with previous examples in demonstrating that such data is suitable for documenting the dispersal of domesticated crops. Nevertheless, our understanding of the first farming communities would be much enhanced by improvements in the recording and publishing of archaeobotanical remains. Seeds should be dated directly wherever possible, particularly the rarer pulses and oil crops. Our use of Simpson's diversity index has shown that outcomes of random processes like founder effects can be tested for. We urge researches to include diverse statistical approaches to test for processes known from theoretical models, which might explain patterns evident in large-scale data. We acknowledge that our results only stand true until further investigations refute them, though we hope that the 'big picture' presented here encourages more detailed and robust data acquisition and manipulation.

Acknowledgements

This work was supported by the European Research Council project EUROFARM led by Dr. M. Vander Linden (FP/20072013; ERC Grant no. 313716); the French National Agency of Research project PROCOME led by Dr. C. Manen (ANR-13-CULT-0001-01); the FNS project led by Dr. L. Martin (Grant no. PZ00P1_161307), and the Swiss National Science Foundation as part of a SNF Professorship (PI: F. Antolín, Grant no. PP00P1_170515).

Akeret, Ö., 2005. Plant remains from a Bell Beaker site in Switzerland, and the beginnings of Triticum spelta (spelt) cultivation in Europe. *Vegetation History and Archaeobotany 14*, 279–286.

Alagich, R., Gardeisen, A., Alonso, N., Rovira, N., Bogaard, A., 2018. Using stable isotopes and functional weed ecology to explore social differences in early urban contexts: The case of Lattara in Mediterranean France. *Journal of Archaeological Science 93*, 135–149.

Alonso, N., 1999. *De la llavor a la farina: els processos agrícoles protohistòrics a la Catalunya occidental.* Monographies d'archéologie méditerranéenne, 4. Lattes: Association pour la Recherche Archéologique en Languedoc Oriental.

Alonso, N., Bouby, L., 2017. Plant Resources from the Bronze Age and the first Iron Age in the northwestern arc of the Mediterranean Basin. *Comptes Rendus Palevol 16*, 363–377.

Andrews, M., McKenzie, B.A., 2007. Adaptation and Ecology. In: Yadav, S. S., McNiel, D. L., Stevenson, S. (Eds.), *Lentil: an ancient crop for modern times.* Springer, Dordrecht, pp. 23–32.

Antolín, F., 2016. *Local, intensive and diverse? Early farmers and plant economy in the North-East of the Iberian Peninsula (5500-2300 cal BC).* Barkhuis Publishing, Groningen.

Antolín, F., Buxó, R., 2011a. L'explotació de les plantes: contribució a la història de l'agricultura i de l'alimentació vegetal del Neolític a Catalunya. In: Bosch, A., Chinchilla, J., Tarrús, J. (Eds.), *El poblat lacustre del Neolític antic de la Draga. Excavacions 2000-2005*. CASC - Museu d'Arqueologia de Catalunya (Monografies del CASC, 9), Girona, pp. 147-174.

Antolín, F., Buxó, R., 2011b. Proposal for the systematic description and taphonomic study of carbonized cereal grain assemblages: a case study of an early Neolithic funerary context in the cave of Can Sadurní (Begues, Barcelona province, Spain). *Vegetation History and Archaeobotany 20*, 53-66.

Antolín, F., Buxó, R., 2012. Chasing the traces of diffusion of agriculture during the Early Neolithic in the western Mediterranean coast. *Rubricatum 5*, 95–102.

Antolín, F., Jacomet, S., 2015., Wild fruit use among early farmers in the Neolithic (5400–2300 cal BC) in the North-East of the Iberian Peninsula: an intensive practice. *Vegetation History and Archaeobotany 24*, 19–33.

Antolín, F., Schäfer, M., (Submitted). Insect pests of pulse crops and their management in Neolithic Europe. *Environmental Archaeology*.

Antolín, F., Buxó, R., Jacomet, S., Navarrete, V., Saña, M., 2014. An integrated perspective on farming in the early Neolithic lakeshore site of La Draga (Banyoles, Spain). *Environmental Archaeology 19*/3, 241–255.

Antolín, F., Jacomet, S., Buxó, R., 2015. The hard knock life. Archaeobotanical data on farming practices during the Neolithic (5400-2300 cal BC) in the NE of the Iberian Peninsula. *Journal of Archaeological Science 61*, 90–104.

Antolín, F., Navarrete, V., Saña, M., Viñerta, Á., Gassiot, E., 2018. Herders in the mountains and farmers in the plains? A comparative evaluation of the archaeobiological record from Neolithic sites in the eastern Iberian Pyrenees and the southern lower lands. *Quaternary International 484*, 75-93.

Arobba D., Panelli C., Caramiello R., Gabriele M., Maggi R., 2017. Cereal remains, plant impressions and 14C direct dating from the Neolithic pottery of Arene Candide Cave (Finale Ligure, NW Italy) *Journal of Archaeological Science: Reports 12*, 395-404.

Aura Tortosa, J. E., Badal, G. E., García Borja, P., García Puchol, O., Pascual Benito, J. L., Pérez Jordà, G., et al. (2005). Cueva de Nerja (Málaga). Los niveles neolíticos de la Sala del Vestíbulo. In: P. Arias, R. Ontañón, & C. García-Moncó (Eds.), *III Congreso del neolítico en la Península Ibérica*. Monografías del Instituto de Investigaciones Prehistóricas de Cantabria, Santander, pp. 975-988.

Badal García, E., Bernabeu Aubán, J., Vernet, J.-L., 1994. Vegetation changes and human action from the Neolithic to the Bronze Age (7000–4000 B.P.) in Alicante, Spain, based on charcoal analysis. *Vegetation History and Archaeobotany 3*, 155–166.

Beeching, A., Berger, J.F., Brochier, J.L., Ferber, F., Helmer, D., Sidi Maamar, H., 2000. Chasséens: agriculteurs ou éleveurs, sédentaires ou nómades ¿ Quels types de milieux, d'économies, de sociétés ? In: *Rencontres meridionales de Préhistoire récente. Troisième sesión, Toulouse 1998*. Archives d'Ecologie Préhistorique, Toulouse, pp. 59-79.

Berger, J. F., Guilaine, J., 2009. The 8200 cal BP abrupt environmental change and the Neolithic transition: A Mediterranean perspective. *Quaternary International 200*, 31–49.

Berrocal, A., Antolín, F., Buxó, R. (In press). Actividades agrícolas en La Draga (Banyoles, Pla de l'Estany): resultados del análisis carpológico de nuevos contextos excavados en el sector A. *Actas del 6° Congreso del Neolítico Peninsular*.

Biagi, P., Shennan, S., Spataro, M., 2005. Rapid rivers and slow seas? New data for the radiocarbon chronology of the Balkan Peninsula. *Prehistoric archaeology and anthropological theory and education. Reports of prehistoric research projects 6–7*, 41–52.

Binder, D., Brochier, E.J., Duday, H., Helmer, D., Marinval, P., Thiébault, S., Wattez, J., 1993. L'abri Pendimoun à Castellar (Alpes-Maritimes). Nouvelles données sur le complexe culturel de la céramique imprimée méditerranéenne dans son contexte stratigraphique. *Gallia préhistoire 35*, 177-251.

Bocquet-Appel, J. P., Naji, S., Vander Linden, M., Kozłowski, J. K., 2009. Detection of diffusion and contact zones of early farming in Europe from the space-time distribution of 14C dates. *Journal of Archaeological Science 36*, 807–820.

Bocquet-Appel, J. P., Naji, S., Vander Linden, M., Kozłowski, J., 2012. Understanding the rates of expansion of the farming system in Europe. *Journal of Archaeological Science 39*, 531–546.

Bogaard, A., 2011. *Plant use and crop husbandry in an early Neolithic village: Vaihingen an der Enz, Baden-Württemberg*. Bonn: Dr.Rudolf Habelt GmbH.

Bogaard, A., Halstead, P., 2015. Subsistence practices and social routine in Neolithic southern Europe. In: Fowler, C., Harding, J., Hofmann, D. (Eds.), *The Oxford Handbook of Neolithic Europe.* Oxford University Press, Oxford, pp. 385–410.

Bonsall, C., Cook, G. T., Pickard, C., McSweeney, K., Sayle, K., Bartosiewicz, L., Radovanović, I., Higham, T., Soficaruy, A., Boroneanţ, A., 2015. Food for thought: re-assessing Mesolithic diets in the Iron Gates. *Radiocarbon 57*/4, 689–699.

Bosch, A., Buxó, R., Palomo, A., Buch, M., Mateu, J., Tabernero, E., Casadevall, J., 1998. *El Poblat neolític de Plansallosa: L'explotació del territori dels primers agricultors-ramaders de l'Alta Garrotxa*. Museu Comarcal de la Garrotxa, Olot.

Bouby, L. 2009. Les restes carpologiques des couches 60 à 47. In: Voruz, J-L. (Eds.), *La grotte du Gardon (Ain) – Volume 1. Le site et la séquence néolithique des couches 60 à 47.* Archives d'Ecologie Préhistorique, Toulouse, pp. 227-230.

Bouby, L., 2014. *L'agriculture dans le Bassin du Rhône du Bronze final à l'Antiquité. Agrobiodiversité, économie, cultures*. Toulouse: Archives d'Ecologie Préhistorique.

Bouby, L., Figueiral, I., 2014. Les ressources végétales du Néolithique ancien nîmois : Mas de Vignoles X et Mas Neuf. In: Perrin, T., Manen, C., Séjalon, P. (Eds.), *Le Néolithique ancien de la plaine de Nîmes (Gard, France)*. Archives d'Ecologie Préhistorique, Toulouse, pp. 339-343.

Bouby, L., Léa, V., 2006. Exploitation de la vesce commune (Vicia sativa L.) au Néolithique moyen dans le Sud de la France. Données carpologiques du site de Claparouse (Lagnes, Vaucluse). *Comptes Rendu Palevol 5(8)*: 973-980.

Bouby, L., Durand, F., Rousselet, O., Manen, C., 2018. Early farming economy in Mediterranean France: fruit and seed remains from the Early to Late Neolithic levels of the site of Taï (ca 5300–3500 cal bc). *Vegetation History and Archaeobotany 28*, 17-34.

Bouby, L., Marinval, P., Durand, F., Guilaine, J., Manen, C., 2016. *Early Neolithic farming economy in the Southern margins of the Massif Central (Southern France): a review of archaeobotanical data*. Poster presented at the 17th International Work Group for Palaeoethnobotany, Paris, 4-9 July 2016.

Buxó, R., 1997. Arqueologia de las plantas. La explotacion economica de las semillas y los frutos en el marco mediterraneo de las Peninsula Iberica. Critica, Barcelona.

Buxó, R., 2004. La explotación de los recursos vegetales en cueva del Toro. In: Martín, D., Camálich, M.D., González, P. (Eds.), *La cueva del Toro (Sierra de El Torcal - Antequera - Málaga). Un modelo de explotación ganadera en el territorio andaluz entre el VI y II milenios ANE.* Monografías de Arqueología, Junta de Andalucía, Sevilla, pp. 267-284.

Buxó, R., Canal, D., 2008. L'agricultura i l'alimentació vegetal. *Quarhis 4*, 54-56.

Buxó, R., Rovira, N., Sauch, C., 2000. Les restes vegetals de llavors i fruits. In: Bosch, A., Chinchilla, J., Tarrús, J. (Eds.), *El poblat lacustre neolític de la Draga. Excavacions de 1990 a 1998*. (Monografies del CASC, 2) Museu d'Arqueologia de Catalunya, Girona, pp. 129-140.

Carra, M., 2012. *Per una storia della cerealicoltura in Italia settentrionale dal Neolitico all'Età del Ferro: strategie adattive e condizionamenti ambientali*. Doctoral dissertation, Università di Bologna, Italy.

Carra, M., Ricciardi, S., 2007. Il Neolitico della pianura reggiana. Studi archeobotanici dell'insediamento di Bazzarola (Reggio Emilia). *Annali dell'Università di Ferrara, Museologia Scientifica e Naturalistica*, volume speciale, pp. 4-6.

Caracuta, V., Vardi, J., Paz, Y., Boarreto, E., 2017. Farming legumes in the pre-pottery Neolithic: New discoveries from the site of Ahihud (Israel). *PLoS ONE 12*/5, 1–28.

Caracuta, V., Weinstein-Evron, M., Kaufman, D., Yeshurun, R., Silvent, J., Boarreto, E., 2016. 14,000-year-old seeds indicate the Levantine origin of the lost progenitor of faba bean. *Scientific Reports 6*, 1–6.

Castelletti, L., Maspero, A., 1992. Analisi di resti vegetali di campo ceresole del Vhò di Piadena e di altri siti neolitici padani. *Natura Bresciana 27*, 289–305.

Castiglioni, E., Rottoli, M., 2015. I resti botanici da Maserà - via Bolzani, Monselice - via Valli e Este - località Meggiaro nel quadro del Neolitico medio-recente e dell'Eneolitico in Italia settentrionale. In: *Dinamiche insediative nel territorio dei Colli Euganei tra Paleolitico e Medioevo,* Atti del Convegno di Studi di archeologia e territorio 27 and 28 November 2009. Beni culturali, pp. 86-92.

Clemente, I., Gassiot, E., Rey, J., Antolín, F., Obea, L., Viñerta, A., Saña, M., 2016. Cueva de Coro Trasito (Tella-Sin, Huesca): Un asentamiento pastoril en el Pirineo central con ocupaciones del Neolítico Antiguo y del Bronce Medio, *I Congreso de Arqueología y Patrimonio Aragonés*, pp. 71-80.

Colledge, S., 2016. The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset 3: Archaeobotanical Data. *Journal of Open Archaeology Data 5*/e1.

Colledge, S., Conolly, J., 2007a. The neolithisation of the Balkans: a review of the archaeobotanical evidence. In: Spataro M., Biagi, P. (Eds.), *A short walk through the Balkans: the first farmers of the Carpathian Basin and adjacent regions.* Società Preistoria Protostoria Friuli-V.G., Trieste, pp. 25–38.

Colledge, S., Conolly, J., 2007b. A review and synthesis of the evidence for the origins of farming on Cyprus and Crete. In: Colledge S., Conolly, J. (Eds.), *The origins and spread of domestic plants in Southwest Asia and Europe.* Left Coast Press, Walnut Creek, CA , pp. 53–74.

Colledge, S., Conolly, J., Shennan, S., 2004. Archaeobotanical evidence for the spread of farming in the Eastern Mediterranean. *Current Anthropology 45*/S4, 35–58.

Colledge, S., Conolly, J., Shennan, S., 2005. The evolution of Neolithic farming from SW Asian origins to NW European limits. *European Journal of Archaeology 8*/2, 137–156.

Conolly, J., Colledge, S., Dobney, K., Vigne, J. D., Peters, J., Stopp, B., Manning, K., Shennan, S. 2011. Meta-analysis of zooarchaeological data from SW Asia and SE Europe provides insight into the origins and spread of animal husbandry. *Journal of Archaeological Science 38,* 538–545.

Conolly, J., Colledge, S., Shennan, S., 2008. Founder effect, drift, and adaptive change in domestic crop use in early Neolithic Europe. *Journal of Archaeological Science 35,* 2797–2804.

Coppola, D., Costantini, L., 1987. Le Néolithique ancien littoral et la diffusion de céréales dans les Pouilles durant le VIe millenaire: les sites de Fontanelle, Torre Canne et Le Macchie. In: J. Guilaine, J., Courtin, J., Roudil, J-L., Vernet, J-L. (Eds.). *Premiéres communautés paysannes en Méditerranée occidentale. Actes du colloque international du CNRS, 26-29 Avril, 1983*. Centre national de la recherche scientifique, Paris, pp. 249–255.

Costantini, L., Lentini, A., 2003. Indagini archeobotaniche sugli intonaci Neolitici di Torre Sabea. In: Guilaine, J., Cremonesi, G. (Eds.), *Torre Sabea. Un establissement du Néolithique ancien en Salento*. École Française de Rome, Rome, pp. 234–245.

Costantini, L., Stancanelli, M., 1994. La preistoria agricola dell'Italia centro-meridionale: il contributo delle indagini archeobotaniche. *Origini 18*, 149–244.

Coward, F., Shennan, S., Colledge, S., Conolly, J., Collard, M., 2008. The spread of Neolithic plant economies from the Near East to northwest Europe: a phylogenetic analysis. *Journal of Archaeological Science 35*, 42–56.

Craufurd, P. Q., Wheeler, T. R., 2009. Climate change and the flowering time of annual crops. *Journal of Experimental Botany*, 2529–2539.

Cubero, J. I., 1981. Origin, taxonomy and domestication. In: Webb, C., Hawtin, G. (Eds.), *Lentils.* Commonwealth Agricultural Bureaux, Slough, pp. 15–38.

de Vareilles, A., Unpublished. *Deeply set roots: an archaeobotanical perspective on the origins of crop husbandry in the western Balkans*, Doctoral dissertation, Institute of Archaeology, University College London.

D'Oronzo, C., Fiorentino, G., 2006. Analisi preliminare dei resti carpologici rinvenuti nel villaggio neolitico di Foggia (località ex-Ippodromo). In: Gravina, A. (Ed.), *Atti del 26 convegno sulla preistoria - protostoria e storia della Daunia. 10-11 Dicembre 2005.* Archeoclub d'Italia, San Severo, pp. 33–38.

D'Oronzo, C., Gaglione, L., Fiorentino, G., 2008. L'analisi archeobotanica in località Monte Calvello (Fg): fasi neolitica e dauna. In: Gravina, A. (Ed.), *Atti del 28 convegno sulla preistoria - protostoria e storia della Daunia. 25-26 Novembre 2007.* Archeoclub d'Italia, San Severo, pp. 49–59.

Drost, C., Vander Linden, M., 2018. Toy story: homophily, transmission and the use of simple models for assessing variability in the archaeological record. *Journal of Archaeological Method and Theory 25*/4, 1087–1108.

Ecocrop, as part of the Food and Agriculture Organization for the United Nations. http://ecocrop.fao.org/ecocrop/srv/en/home (accessed 3rd April 2019).

Edo, M., Blasco, A., Villalba, M.J., 2011. La cova de Can Sadurní, guió sintètic de la prehistòria recent de Garraf. In: Blasco, A., Edo, M., Villalba, M.J. (Eds.), *La cova de Can Sadurní i la Prehistòria de Garraf. Recull de 30 anys d'investigació*. EDAR-Hugony, Milano, pp. 13-95.

Erroux, J., 1976. Les debuts de l'agriculture en France : les céréales. In : Guilaine, J. (ed.), *La préhistoire française*. CNRS, Paris, pp. 186-191.

Erroux, J., 1979. Détermination de graines carbonisées. In : Roudil, J.L., Roudil, O, Soulier M. (Eds.), *La grotte de l'Aigle à Méjannes-le-Clap (Gard) et le Néolithique ancien du Languedoc oriental*. Mémoires de la Société Languedocienne de Préhistoire, 1, Montpellier, pp. 75.

Erroux, J., 1988. Etude de sgraines et fruits de la grotte Saint-Marcel (Ardèche). *Ardèche Archéologie*, 5: 42-45.

Erroux, J., 1992. Diagnose de quelques débris de végétaux de l'abri du Roc Troué (Sainte-Eulalie-de-Cernon, Aveyron). *Bulletin de la Société Préhistorique Française, 89(7)* : 218-219.

Espejo Herrerías, M.M., Cabello Ligero, L., Cantalejo Duarte, P., Becerra Martín, S., Ramos Muñoz, J., Ledesma Conejo, P., Santos Arévalo, F.J., & Peña-Chocarro, L. (2013). El aprovechamiento de la campiña entre Teba y Ardales (Málaga) por los agricultores del Neolítico el caso del Cerro de la Higuera. *Mainake*, 34, 227–244.

Evett, D., Renfrew, J., 1971. L'agricoltura neolitica italiana: una nota sui cereali. *Rivista di Scienze Preistoriche 26*/2, 403–409.

Filipović, D., Obradović, Đ., 2013. Archaeobotany at Neolithic sites in Serbia: a critical overview of the methods and results. In: Vitezović, S., Miladinović, N. (Eds.), *Bioarchaeology 1. Developments and trends in bioarchaeological research in the Balkans.* Srpsko Arheološko Društvo, Belgrade, pp. 25–55.

Fiorentino, G., Caldara, M., De Santis, V., D'Oronzo, C., Muntoni, I. M., Simone, O., Primavera, M., Radina, F., 2013. Climate changes and human-environment interactions in the Apulia region of southeastern Italy during the Neolithic period. *The Holocene 23*/9, 1297–1316.

Forenbaher, S., Kaiser, T., Miracle, P., 2013. Dating the East Adriatic Neolithic. *European Journal of Archaeology 16*, 589–609.

Forenbaher, S., Miracle, P., 2005. The spread of farming in the Eastern Adriatic. *Antiquity 79*, 514–528.

Forenbaher, S., Perhoč, Z., 2015. Lithic artifacts from Nakovana (Pelješac): Continuity and change from Early Neolithic until the end of Prehistory. *Prilozi. Instituta za Arheologija u Zagrebu 32*, 5–74.

Fuller, D. Q., Stevens, C. J., McClatchie, M., 2014. Routine activities, tertiary refuse and labour organisation: social inferences from everyday archaeobotany. In: Madella, M., Lancelotti, C., Savard, M. (Eds.), *Ancient plants and people. Contemporary trends in archaeobotany.* University of Arizona Press, Arizona, pp. 174–217.

Gaastra, J., de Vareilles, A., Vander Linden, M., 2019. Bones and Seeds: an integrated approach to understanding the spread of farming across the western Balkans. *Environmental Archaeology*. DOI: 10.1080/14614103.2019.1578016.

Garciá-Puchol, O., Diez Castillo, A. A., Pardo-Gordó, S., 2017. Timing the western Mediterranean last hunter-gatherers and first farmers. In: García-Puchol, O., Salazar-García, D. C. (Eds.), *Times of Neolithic transition along the western Mediterranean*, Springer International Publishing AG, 69–99. DOI: 10.1007/978-3-319-52939-4.

Gardener, M., 2014. *Community ecology. Analytical methods using R and Excel.* Pelagic Publishing, Exeter.

Guilaine, J., 2001. La diffusion de l'agriculture en Europe: une hypothèse arythmique. *Zephyrus 54*, 267–272.

Guilaine, J., 2003. *De la vague à la tombe. La conquête Néolithique de la Méditerranée*, Paris: Le Seuil.

Guilaine, J., 2013. The neolithic transition in Europe: some comments on gaps, contacts, arrythmic model and genetics. In: Starnini, E. (ed.), *Unconformist archaeology, papers in honour of Paolo Biagi*, British Archaeological Reports, International Series 2528, 55–64.

Guilaine, J., 2017. The Neolithic transition: from the eastern to the western Mediterranean. In: Garciá-Puchol, O., Salazar-García, D. C. (Eds.), *Times of Neolithic transition along the western Mediterranean*, Springer International Publishing AG, 15-29. DOI: 10.1007/978-3-319-52939-4.

Guilaine, J. 2018. A personal view of the neolithisation of the western Mediterranean. *Quaternary International 470*, 211–225.

Hahn, M. W., Bentley, R. A., 2003. Drift as a mechanism for cultural change: an example from baby names. *Proceedings of the Royal Society of London B.* DOI: 10.1098/rsbl.2003.0045.

Henderson, D. A., Baggaley, A. W., Shukurov, A., Boys, R. J., Sarson, G. R., Golightly, A., 2014. Regional variations in the European Neolithic dispersal: the role of the coastlines. *Antiquity 88*, 1291–1302.

Hunt, H., Vander Linden, M., Liu, X., Motuzaite-Matuzeviciute, G., Jones, M. K., 2008. Millets across Eurasia: chronology and context of early records of the genera Panicum and Setaria from archaeological sites in the Old World. *Vegetation History and Archaeobotany 17*/Supplement 1, S5–S18.

Huntley, J., 1996. The plant remains. In: Chapman, J., Shiel, R. and Batović, Š. (Eds.), *The changing face of Dalmatia. Archaeological and ecological studies in a Mediterranean landscape.* Leicester University Press, Leicester, pp. 187–189.

Iannucci, A., Terribile, M. R., Martiniello, P., 2008. Effects of temperature and photoperiod on flowering time of forage legumes in a Mediterranean environment. *Field Crops Research 106*/2, 156–162.

Ivanova, M., De Cupere, B., Ethier, J., Marinova, E., 2018. Pioneer farming in Southeast Europe during the early sixth millennium BC: climate-related adaptations in the exploitation of plants and animals. *PloS one 13*/5, e0197225.

Jacomet, S., Brombacher, C., Dick, M., 1989. *Archäobotanik am Zürichsee. Ackerbau, Sammelwirtschaft und Umwelt von neolithischen und bronzezeitlichen Seeufersiedlungen im Raum Zürich. Ergebnisse von Untersuchungen pflanzlicher Makroreste der Jahre 1979-1988.* Orell Füssli Verlag, Zürich.

Jalut, G., Esteban Amat, A., Bonnet, L., Gauquelin, T., Fontugne, M., 2000. Holocene climatic changes in the western Mediterranean, from South-East France to South-East Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology 160*, 255–290.

Jones, G., 1987. Botanical remains, in Lagnano da Piede I - an early Neolithic village in the Tavoliere. *Origini 13*, 270.

Jones, G., Halstead, P., 1995. Maslins, mixtures and monocrops: on the interpretation of archaeobotanical crop samples of heterogeneous composition. *Journal of Archaeological Science 22*/1, 103–114.

Jones, G., Valamoti, S. M., Charles, M., 2000. Early crop diversity: A "new" glume wheat from northern Greece. *Vegetation History and Archaeobotany*, 133–146.

Jover Maestre, F. J., Pastor Quiles, M., Torregrosa Giménez, P., 2019. Advances in the analysis of households in the early neolithic groups of the Iberian Peninsula: Deciphering a partial archaeological record. *Journal of Anthropological Archaeology 53*, 1–21.

Kislev, M., Hartmann, A., Galili, E., 2004. Archaeobotanical and archaeoentomological evidence from a well at Atlit-Yam indicates colder, more humid climate on the Israeli coast during the PPNC period. *Journal of Archaeological Science 31*, 1301–1310.

Kohler-Schneider, M., 2003. Contents of a storage pit from late Bronze Age Stillfried, Austria: another record of the "new" glume wheat. *Vegetation History and Archaeobotany 12*, 105–111.

Komšo, D., 2005. Kargadur. In: Mesić, J. (Ed.), *Hrvatski arheološki godišnjak, Vol 2.* Ministarstvo Kulture, pp. 212–214.

Krauss, R., Marinova, E., De Brue, H., Weninger, B., 2017. The rapid spread of early farming from the Aegean into the Balkans via the Sub-Mediterranean-Aegean Vegetation Zone. *Quaternary International*, 1–18.

Kreuz, A., 1990. Die ersten Bauern Mitteleuropas - eine archäobotanische Untersuchung zu Umwelt und Wirtschaft der ältesten Bandkeramik. *Analecta Praehistorica Leidensia 23*, 1–256.

Kreuz, A., Marinova, E., Schäfer, E., Wiethold, J., 2005. A comparison of early Neolithic crop and weed assemblages from the Linearbandkeramik and the Bulgarian Neolithic cultures: differences and similarities. *Vegetation History and Archaeobotany 14*/4, 237–258.

Kreuz, A., Märkle, T., Marinova, E., Rösch, M., Schäfer, E., Schamuhn, S., Zerl, T., 2014. The Late Neolithic Michelsberg culture – just ramparts and ditches? A supraregional comparison of agricultural and environmental data. *Praehistorische Zeitschrift 89*/1, 72–115.

López Sáez, J. A., Pérez Díaz, S., Alba Sánchez, F., 2011. Estudios sobre evolución del paisaje: palinología. In: Torregrosa Giménez, P., Jover Maestre, F. J., Seguí, López, E. (Eds.), *Benàmer (Muro d'Alcoi, Alicante). Mesolíticos y neolíticos en las tierras meridionales valencianas*. Servicio de Investigación Prehistórica, Valencia, pp. 107–112.

Lyman, R. L., 2015. On the variable relationship between NISP and NTAXA in bird remains and animal remains. *Journal of Archaeological Science 53*, 291–296.

Manen, C., Perrin, T., Guilaine, J., Bouby, L., Bréhard, S., Briois, F., Durand, F., Marinval, P., Vigne, J.-D., 2018a. The neolithic transition in the western Mediterranean: a complex and non-linear diffusion process - the radiocarbon record revisited. *Radiocarbon 61*/2, 531–571.

Manen, C., García Martínez de Lagrán, I., López-Montalvo, E., 2018b. The Neolithisation of the western Mediterranean: new debates about an old issue. *Quaternary International 472*, 169–171.

Manen, C., Vigne, J.-D., Loirat, D., Bouby, L., 2001. L'Aspre del Paradis à Corneilla-del-Vercol (Pyrénées-Orientales): contribution à l'étude du Néolithique ancien et final. *Bulletin de la Société Préhistorique Française, 98(3),* 505-528.

Manning, K., Downey, S. S., Colledge, S., Conolly, J., Stopp, B., Dobney, K., Shennan, S., 2013. The origins and spread of stock-keeping: the role of cultural and environmental influences on early Neolithic animal exploitation in Europe. *Antiquity 87*, 1046–1059.

Marijanović, B., 2009. *Crno Vrilo 1*, Zadar: Sveučilišteu Zadru.

Marinova, E., Valamoti, S. M., 2014. Crop diversity and choices in the Prehistory of SE Europe: cultural and environmental factors shaping the archaeobotanical record of northern Greece and Bulgaria. In: Chevalier, A., Marinova, E., Peña-Chocarro, E. (Eds.), *Plants and people. Choices and diversity through time*, Oxford: Oxbow Books, 64–74.

Marinval, P., 1988. Anàlisi paleocarpològic de la Balma de la Margineda Sant Julia (Andorra). In: Guilaine, J. (Ed.), *Les investigacions a La Balma de La Margineda (1979-1985)*. Institut d'Estudis Andorrans, Perpinyà, pp. 131-139.

Marinval, P., 1993. Analyse carpologique du Roc de Dourgne. In: Guilaine, J. (Ed.). *Dourgne. Derniers chasseurs-collecteurs et premiers éleveurs da la haute-vallée de l'Aude*. CASR/ARETA, Toulouse/Carcassonne, pp. 415-416.

Marinval, P., 2003a. Les paléo-semences carbonisées de Torre Sabea: méthodologie et résultats. In: Guilaine, J., Cremonesi, G. (Eds.), *Torre Sabea. Un establissement du Néolithique ancien en Salento.* École Française de Rome, Rome, pp. 228–233.

Marinval, P., 2003b. Torre Sabea et la première agriculture en Méditerranée Centrale. In: Guilaine, J., Cremonesi, G. (Eds.), *Torre Sabea. Un establissement du Néolithique ancien en Salento.* École Française de Rome, Rome, pp.316–324.

Märkle, T., Rösch, M., 2018. Experiments on the effects of carbonization on some cultivated plant seEds. *Vegetation History and Archaeobotany 17*: 257-263.

Martin, L., 2015. Plant economy and territory exploitation in the Alps during the Neolithic (5000–4200 cal bc): first results of archaeobotanical studies in the Valais (Switzerland). *Vegetation History and Archaeobotany 24*, 63-73.

Martin, L., Delhon, C., Dufraisse, A., Thiébault, S., Besse, M., (In press). De l'arolle ou du chêne? Mobilité verticale et exploitation des ressources végétales au Néolithique dans les Alpes occidentales vus par l'archeobotanique. In: Deschamps, M., Costamagno, S., Milcent, P-Y., Pétillon, J-M., Renard, C., Valdeyron, N. (Eds.), *La conquête de la montagne: des premières occupations humaines à l'anthropisation du milieu*, Actes du 142^{e} congrès national du CTHS, Pau 2017, éditions du CTHS.

Martín, A., Edo, M., Tarrús, J., Clop, X., 2010. Le Néolithique ancien de Catalogne (VIe-première moitié du Ve millénaire av. J.-c.) - Les séquences chronoculturelles. In: Manen, C., Convertini, F., Binder, D., Sénépart, I. (Eds.), *Premières societés paysannes de Méditerrannée occidental. Structures des productions céramiques.* Mémoire 51 Société Préhistorique française, Toulouse, pp. 197–214.

Marziani, G., Tacchini, G., 1996. Palaeoecological and palaeoethnological analysis of botanical macrofossils found at the Neolithic site of Rivaltella ca'Romensini, northern Italy. *Vegetation History and Archaeobotany 5*, 131-136.

Mauri, A., Davis, B. A., Collins, P. M., Kaplan, J. O., 2015. The climate of Europe during the Holocene: a gridded pollen-based reconstruction and its multi-proxy evaluation. *Quaternary Science Reviews 112*, 109–127.

Mazzucco, N., Guilbeau, D., Petrinelli-Pannocchia, C., Gassin, B., Ibáñez, J. J., Gibaja, J. F., 2017. Harvest time: Crop-reaping technologies and the Neolithisation of the central Mediterranean. *Antiquity 91*/356, 1–5.

McClatchie, M., Bogaard, A., Colledge, S., Whitehouse, N. J., Schulting, R. J., Barratt, P., McLaughlin, T. R., 2014. Neolithic farming in north-western Europe: Archaeobotanical evidence from Ireland. *Journal of Archaeological Science 51*, 206–215.

McClatchie, M., Fuller, D. Q., 2014. Leaving a lasting impression. Arable economies and cereal impressions in Africa and Europe. In: Stevens, C. J., Nixon, S., Murray, M. A., Fuller, D. Q. (Eds.), *Archaeology of African plant use.* Left Coast Press, Walnut Creek, CA, pp. 259–265.

McClure, S., Podrug, E., Moore, A., Culleton, B. J., Kennett, D. J., 2014. AMS 14C chronology and ceramic sequences of early farmers in the eastern Adriatic. *Radiocarbon 56*/3, 1019–1038.

McPherson, M., Smit-Lovin, L., Cook, J. M., 2001. Birds of a feather: homophily in social networks. *Annual Review of Sociology 27*, 425–444.

Mercuri, A.M., Allevato, E., Arobba, D., Bandini Mazzanti, M., Bosi, G., Caramiello, R., *et al*., 2015. Pollen and macroremains from Holocene archaeological sites: A dataset for the understanding of the bio-cultural diversity of the Italian landscape. *Review of Palaeobotany and Palynology 218*, 250–266.

Motuzaite-Matuzeviciute, G., Staff, R. A., Hunt, H., Liu, X., Jones, M. K., 2013. The early chronology of broomcorn millet (Panicum miliaceum) in Europe. *Antiquity 87*, 1–5.

Müller, J., 1994. *Das Ostadiatische Frühneolithikum.* Wissenschaftsverlag volker spiess, Berlin.

Nenadić, O., Greenacre, M., 2007. Correspondence Analysis in R, with two- and three-dimensional graphics: The ca package. *Journal of Statistical Software 20*/3, 1–13.

Nesbitt, M., Samuel, D., 1996. From staple crop to extinction? The archaeology and history of the hulled wheats. In: Padulosi, S., Hammer, K., Heller, J. (Eds.), *Hulled wheats. Promoting the conservation and use of underutilized and neglected crops. Proceedings of the First International Workshop on Hulled Wheats, 21-22 July 1995, Castelvecchio Pascoli, Tuscany, Italy.* International Plant Genetic Resources Institute, Rome, pp. 41–101.

Nisbet, R., 1982. Le analisi archeobotaniche del villaggio neolitico della Villa Comunale (Foggia). *Origini 11*, 175–182.

Nisbet, R., 1995. I resti macrobotanici. In: Biagi, P. (Ed.), *L'insediamento neolitico di Ostiano-Dugali Alti (Cremona) nel suo contesto ambientale ed economico*, Brescia: Museo Civico di Scienze Naturale di Brescia. Monografie di «Natura Bresciana» 22, 104–106.

Oksanen, J., Guillaume Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R. B., Simpson, G. L. Solymos, P., Stevens, M. H., Szoecs, E., Wagner, H., 2019. *vegan: Community Ecology*, Https://CRAN.R-project.org/package=vegan, Package. R package version 2.5-4.

Orton, D., Gaastra, J., Vander Linden, M., 2016. Between the Danube and the deep blue sea: zooarchaeological meta-analysis reveals variability in the spread and development of Neolithic farming across the western Balkans. *Open Quaternary 2*/6, 1–26.

Pallarès, M., Bordas, A., Mora Torcal, R., 1997. El proceso de neolitización en los Pirineos orientales. Un modelo de continuidad entre los cazadores-recolectores neolíticos y los primeros grupos agropastoriles. *Trabajos de Prehistoria 54*, 121-141.

Panagiotakopulu, E., Buckland, P. C., 2018. Early invaders: farmers, the granary weevil and other uninvited guests in the Neolithic. *Biological invasions 20*, 219–233.

Pearce, M.J., 2013. *Rethinking the North Italian Early Neolithic*. Accordia Research Institute, University of London, London.

Peña-Chocarro, L., 1999. *Prehistoric agriculture in Southern Spain during the Neolithic and the Bronze Age.* British Archaeological Reports International Series 818, Oxford.

Peña-Chocarro, L. and Zapata, L., 2010. Neolithic agriculture in southwestern Mediterranean region. In J. F. Gibaja Bao & A. F. Carvalho (Eds.), Os últimos caçadores-recolectores e as primeiras comunidades produtoras do sul da Península Ibérica e do norte de Marrocos, Promontoria Monográfica (Vol. 15, pp. 191–198).

Peña-Chocarro, L., Zapata Peña, L., 2014. Versatile hulled wheats: farmers' traditional uses of three endangered crop species in the western Mediterranean. In: Chevalier, A., Marinova, E., Peña-Chocarro, L. (Eds.), *Plants and people. Choices and diversity through time.* Oxbow Books, Oxford, pp. 276–281.

Peña-Chocarro, L., Pérez-Jordá, G., Morales, J., 2018. Crops of the first farming communities in the Iberian Peninsula. *Quaternary International 470*, 369–382.

Peña-Chocarro, L., Zapata, L., García Gazólaz, J., González Morales, M., Sesma Sesma, J., G. Straus, L., 2005. The spread of agriculture in northern Iberia: new archaeobotanical data from El Mirón cave (Cantabria) and the open-air site of Los Cascajos (Navarra). *Vegetation History and Archaeobotany 14*, 268-278.

Peña-Chocarro, L., Zapata Peña, L., González Urquijo, J. E., Ibáñez Estévez, J. J., 2009. Einkorn (Triticum monococcum L.) cultivation in mountain communities of the western Rif (Morocco): an ethnoarchaeological project. In: Fairbairn, A., Weiss, E. (Eds.), *From foragers to farmers. Papers in honour of Gordon C. Hillman*. Oxbow Books, Oxford, pp. 103–111.

Pérez-Jordà, G., 2005. Nuevos datos paleocarpológicos en niveles neolíticos del País Valenciano. In: P. Arias, R. Ontañón, C. García-Moncó (Eds.): *III Congreso del Neolítico en la Península Ibérica (Santander 2003)*. Universidad de Cantabria, Santander, pp. 73-82.

Pérez-Jordà, G., 2010. Estudio paleocarpológico del Cingle del Mas Cremat. In: Vizcaíno León, D. (Ed.), *El cingle del Mas Cremat (Portell de Morella, Castellón). Un asentamiento en altura con ocupaciones del mesolítico reciente al neolítico final*. Generalitat Valenciana-Renomar-EIN Mediterráneo, D.L., Valencia, pp. 149-155.

Pérez-Jordà, G., 2013. *La agricultura en el País Valenciano entre el VI y el I milenio a. C.*, Departament de Prehistòria i Arqueologia. Universitat de València, Valencia.

Pérez-Jordá, G., Peña-Chocarro, L., 2013. Agricultural production between the 6th and the 3rd millennium cal BC in the central part of the Valencia region (Spain). In: Groot, M., Lentjes, D., Zeiler, J. (Eds.), *Barely surviving or more than enough? The environmental archaeology of subsistence, specialisation and surplus food production.* Sidestone, Leiden, pp. 81–99.

Pérez-Jordá, G. Peña-Chocarro, L. Morales Mateos, J., Zapata, L. 2017. Evidence for early crop management practices in the western Mediterranean: latest data, new developments and future perspectives. In: Garciá-Puchol, O., Salazar-García, D. C. (Eds.), *Times of Neolithic transition along the western Mediterranean*, Springer International Publishing AG, pp. 171–198. DOI: 10.1007/978-3-319-52939-4.

Pérez-Losada, J., Fort, J., 2011. Spatial dimensions increase the effect of cultural drift. *Journal of Archaeological Science 38*/6, 1294–1299.

Pilaar Birch, S., Vander Linden, M., 2018. A long hard road... Reviewing the evidence for environmental change and population history in the eastern Adriatic and western Balkans during the Late Pleistocene and Early Holocene. *Quaternary International 465*, 177–191.

Porčić, M., 2018. Evaluating social complexity and inequality in the Balkans between 6500 and 4200 BC. *Journal of Archaeological Research*. DOI: 10.1007/s10814-018-9126-6.

Prat, G., Antolín, F., Alonso, N. (Submitted): A socioeconomic analysis of the changes in underground storage practices in the Northwestern Mediterranean Arc: from the earliest farmers to the first urban centres. *Antiquity*.

Primavera, M., Fiorentino, G., 2011. Archaeobotany as an in-Site/off-Site tool for paleoenvironmental research at Pulo di Molfetta (Puglia, south-eastern Italy). In: Turbanti-Memmi, I. (Ed.), *Proceedings on the 37th international symposium on archaeometry. 12-16 May 2008, Sienna.* Springer, Berlin, Heidelberg, pp. 421–426.

R Development Core Team. 2008. R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. ISBN 3-900051- 07-0, URL http://www.R-project.org.

Reed, K., 2015. From the field to the hearth: plant remains from Neolithic Croatia (ca. 6000–4000 cal BC). *Vegetation History and Archaeobotany*, 601–619.

Reed, K., Colledge, S., 2016. Plant economies in the Neolithic eastern Adriatic: archaeobotanical results from Danilo and Pokrovnik. *Journal of Dalmatian archaeology and history 109*/1, 9–23.

Renfrew, J., 1979. The first farmers in South East Europe. *Archaeo-Physika 8*, 243–265.

Revelles, J., Antolín, F., Berihuete, M., Burjachs, F., Buxó, R., Caruso, L., López, O., Palomo, A., Piqué, R., Terradas, X., 2014. Landscape transformation and economic practices among the first farming societies in Lake Banyoles (Girona, Spain). *Environmental Archaeology 19*, 298–310.

Rigaud, S., Manen, C., García-Martínez de Lagrán, I., 2018. Symbols in motion: Flexible cultural boundaries and the fast spread of the Neolithic in the western Mediterranean. *PLoS ONE 13*/5, e0196488.

Rössner, C., Deckers, K., Benz, M., Özkaya, V., Riehl, S., 2018. Subsistence strategies and vegetation development at Aceramic Neolithic Körtik Tepe, southeastern Anatolia, Turkey. *Vegetation History and Archaeobotany 27*, 15–29.

Rottoli, M., 1993. “La Marmotta”, Anguillara Sabazia (RM). Scavi 1989. Analisi paletnobotaniche: prime risultanze, Appendice 1. In: Fugazzola Delpino, M.A., (Ed.), “La Marmotta” (Anguillara Sabazia, RM). Scavi 1989. Un abitato perilacustre di età neolitica. *Bullettino di Paletnologia Italiana*, 84, n.s II, pp. 305–315.

Rottoli, M. (In press). Agricoltura, raccolta e uso del legno nel sito neolitico di Lugo di Romagna, Fornace Gattelli.

Rottoli, M., Castiglioni, E., 2009. Prehistory of plant growing and collecting in northern Italy, based on seed remains from the early Neolithic to the Chalcolithic (c. 5600–2100 cal B.C.). *Vegetation History and Archaeobotany 18*, 91–103.

Rottoli, M., Pessina, A., 2007. Neolithic agriculture in Italy: an update of archaeobotanical data with particular emphasis on northern settlements. In: Colledge, S., Conolly, J. (Eds.), *The origins and spread of domestic plants in Southwest Asia and Europe*, Walnut Creek, CA: Left Coast Press, 141–153.

Rottoli, M., Cavulli, F., Pedrotti, A., 2015. L'agricoltura di Lugo di Grezzana (Verona): considerazioni preliminari. In: *Preistoria e protostoria del Veneto.* Istituto italiano di preistoria e protostoria, Soprintendenza per i beni archeologici del Veneto: Università degli studi di Padova, pp. 109-116.

Rovira, N., 2007. *Agricultura y gestión de los recursos vegetales en el sureste de la Península Ibérica durante la Prehistoria reciente*. Doctoral dissertation, Universitat Pompeu Fabra, Barcelona.

Salavert, A., 2010. Le pavot (Papaver somniferum) à la fin du 6^{e} millénaire av. J.-C. en Europe occidentale. *Anthropobotanica 3*/1, 3–16.

Salavert, A., Martin, L., Antolín, F., Zazzo, A., 2018. The opium poppy in Europe: exploring its origin and dispersal during the Neolithic. *Antiquity 92*/364. DOI:10.15184/aqy.2018.154

Sargent, A., 1987. Relazione sui resti paleobotanici di Coppa Nevigata. In: *Atti della XXVI ruinione scientifica. Il neolitico in Italia*, Firenze: Instituto Italiano di Preistoria e Protostoria, Volume II., 761–764.

Sarpaki, A., 1995. Toumba Balomenou, Chaeronia: plant remains from the Early and Middle Neolithic levels. In: Kroll, H., Pasternak, R. (Eds.), *Res Archaeobotanichae: 9th Symposium, IWGP*. Oetker-Voges, Kiel, pp. 281–300.

Savard, M., 2000. *Etude de l'assemblage carpologique de la Baume de Fontbrégoua (Var) du Paléeolithique final au Chasséen récent*. Mémoire de DEA. Université Panthéon-Sorbonne, Paris.

Schilperoord, P., 2017. *Kulturpflanzen in der Schweiz: Schlafmohn*, Alvaneu: Verein für alpine Kulturpflanzen.

Shennan, S., Steele, J., 2000. Spatial and chronological patterns in the neolithisation of Europe. <http://archaeologydataservice.ac.uk/archives/view/c14_meso/>.

Smith, A., 2014. The use of multivariate statistics within archaeobotany. In: Marston, J. M., d'Alpoim Guedes, J., Warinner, C. (Eds.), *Method and theory in paleoethnobotany.* University Press of Colorado, Boulder, pp. 181–204.

Stevens, C. J., Murphy, C., Roberts, R., Lucas, L., Silva, F., Fuller, D. Q., 2016. Between China and South Asia : A middle Asian corridor of crop dispersal and agricultural innovation in the Bronze Age. *The Holocene 26*/10, 1541–1555.

Stika, H-P. 2005. Early Neolithic agriculture in Abrona, Provincia Soria, central Spain. *Vegetation History and Archaeobotany 14*, 189–197.

Tafuri, M.A, Rottoli, M., Cupitò, M., Pulcini, M.L., Tasca, G., Carrara, N., Bonfanti, F., Salzani, L., Canci, A., 2018. Estimating C4 plant consumption in Bronze Age Northeastern Italy through stable carbon and nitrogen isotopes in bone collagen. *International Journal of Osteoarchaeology 28(2)*, 131-142.

Thomas, J., 2003. Thoughts on the 'Repacked' Neolithic Revolution. *Antiquity 77*/295, 67–74.

Ucchesu, M. Sau, S., Lugliè, C., 2017. Crop and wild plant exploitation in Italy during the Neolithic period: New data from Su Mulinu Mannu, Middle Neolithic site of Sardinia. *Journal of Archaeological Science: Reports 14*, 1–11.

Valamoti, S. M., 2005. Grain versus chaff: Identifying a contrast between grain-rich and chaff-rich sites in the Neolithic of northern Greece. *Vegetation History and Archaeobotany 14*/4, 259–267.

Valamoti, S.M., 2011. Seeds for the dead? Archaeobotanical remains from Mavropigi near Kozani, site Filotsairi. *The Archaeological Work in Upper Macedonia, 2009* (*1*), 245–257.

Valamoti, S. M., 2013. Millet, the late comer: on the tracks of Panicum miliaceum in prehistoric Greece. *Archaeological and Anthropological Sciences 8*, 51–63.

Valamoti, S. M., Kotsakis, K., 2007. Transitions to agriculture in the Aegean: the archaeobotanical evidence. In: Colledge, S., Conolly, J. (Eds.), *The origins and spread of domestic plants in Southwest Asia and Europe*, Walnut Creek, CA: Left Coast Press, 75–91.

Vander Linden, M., 2011. To Tame a Land: Archaeological cultures and the spread of the Neolithic in western Europe. In: Roberts, B.W., Vander Linden, M. (eds), *Investigating Archaeological Cultures: Material Culture, Variability, and Transmission.* Springer-Verlag, New York, pp. 289–319. DOI: 10.1007/978-1-4419-6970-5.

Vaquer, J., Ruas, M.P., 2009. La grotte de l'Abeurador, Félines-Minervois (Hérault): occupations humaines et environnement du Tardiglaciaire à l'Holocène. In: *De Méditerranée et d'ailleurs… Mélanges offerts à Jean Guilaine*. Archives d'Ecologie Préhistorique, Toulouse, pp. 761-792.

Vital, J., avec la collaboration de Bouby, L., Jallet, F., Rey, P.-J., 2007. Un autre regard sur le gisement du boulevard périphérique nord de Lyon (Rhône) au Néolithique et à l'âge du Bronze. *Gallia Préhistoire*, 49: 1-126.

Weller, J. L., Ortega, R., 2015. Genetic control of flowering time in legumes. *Frontiers in plant science 6*/April, 207.

Whitford, B. R., 2018. Characterizing the cultural evolutionary process from eco-cultural niche models: niche construction during the Neolithic of the Struma River Valley (c. 6200–4900 BC). *Archaeological and Anthropological Sciences*.

Wickham, H., 2016. *ggplot2: Elegant Graphics for Data Analysis*, New York: Springer-Verlag.

Wilson, D. G., 1984. The carbonisation of weed seeds and their representation in macrofossil assemblages. In: Van Zeist, W., Casparie, W. (Eds.), *Plants and ancient man.* A.A. Balkema, Rotterdam, pp. 201–206.

Zapata, L., Peña-Chocarro, L., Pérez-Jordá, G., Stika, H-P., 2004. Early neolithic agriculture in the Iberian peninsula. *Journal of World Prehistory*, 283–325.

Zilhão, J. 2001. Radiocarbon evidence for maritime pioneer colonization at the origins of farming in west Mediterranean Europe. *Proceedings of the National Academy of Sciences of the United States of America 98*/24, 14180–14185.

Zohary, D., Hopf, M., Weiss, E., 2012. *Domestication of crops in the Old World.* 4th Edition. Oxford University Press, Oxford.

Title
One Sea but many Routes to Sail. The early maritime dispersal of Neolithic crops from the Aegean to the western Mediterranean

Corresponding author: A. de Vareilles (ak.vareilles@gmail.com)

Authorship Statements

A. de Vareilles – Conceptualization, Data curation, Formal analyses, Investigation, Methodology, Project administration, Writing: original draft, Writing: review and editing

L. Bouby - Data curation, Writing: review and editing

A. Jesus - Data curation, Writing: review and editing

L. Martin - Data curation, Writing: review and editing

M. Rottoli - Data curation, Writing: review and editing

M. Vander Linden - Data curation, Formal analyses, Funding acquisition, Methodology, Software, Validation, Visualization, Writing: review and editing

F. Antolín - Conceptualization, Data curation, Formal analyses, Investigation, Funding acquisition Methodology, Project administration, Writing: review and editing

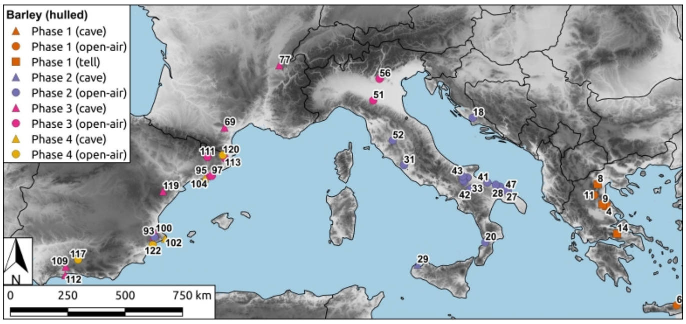


Figure 1S: Distribution map of sites with hulled barley (*Hordeum vulgare* subsp. v*ulgare*)

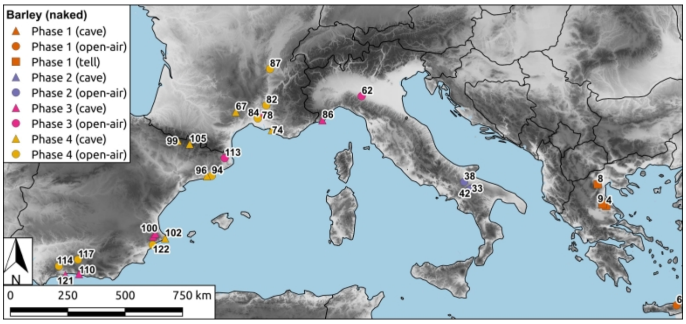


Figure 2S: Distribution map of sites with naked barley (*H. vulgare* var. *nudum*)

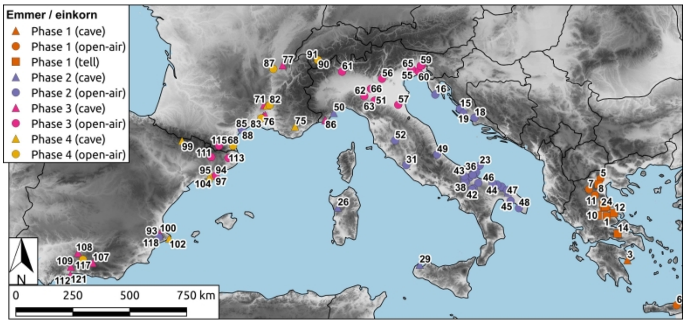


Figure 3S: Distribution map of sites with einkorn and/or emmer (*Triticum monococcum/dicoccum*)

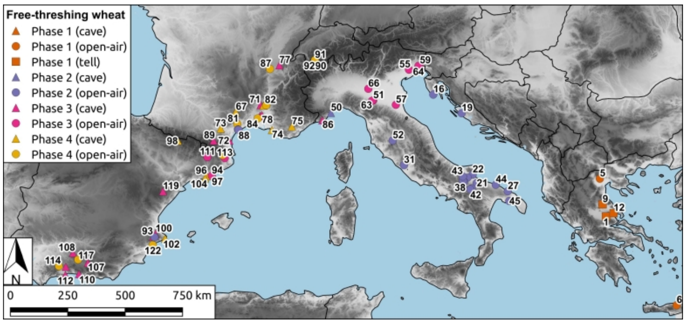


Figure 4S: Distribution map of sites with free-threshing wheat (*T. aestivum/durum*)

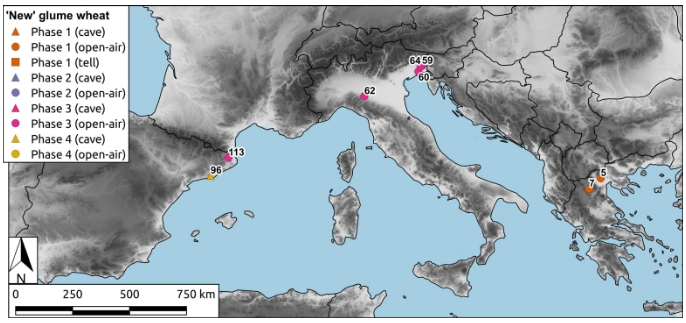


Figure 5S: Distribution map of sites with the 'new' glume wheat

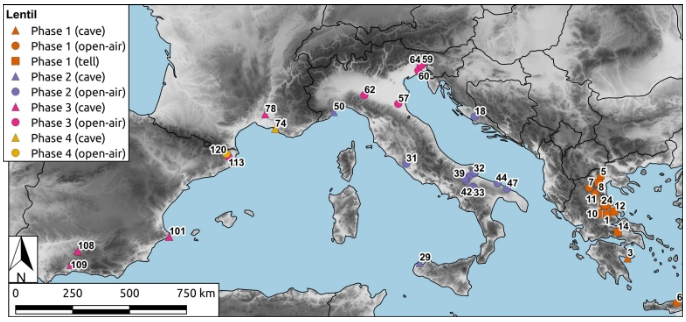


Figure 7S: Distribution map of sites with lentil (*Lens culinaris*)

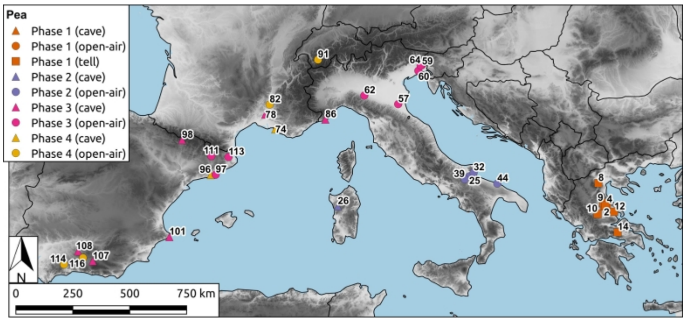


Figure 8S: Distribution map of sites with pea (*Pisum sativum*)

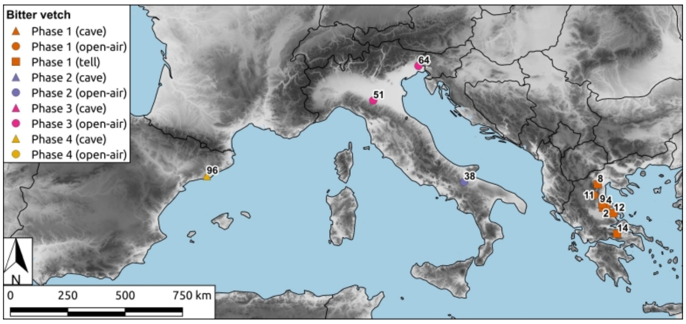


Figure 9S: Distribution map of sites with bitter vetch (*Vicia ervilia*)

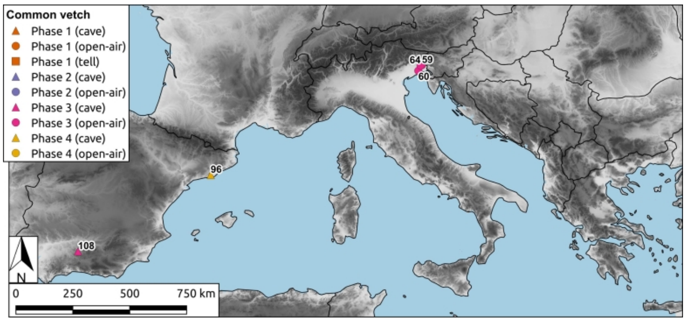


Figure 10S: Distribution map of sites with common vetch (*Vicia sativa*)

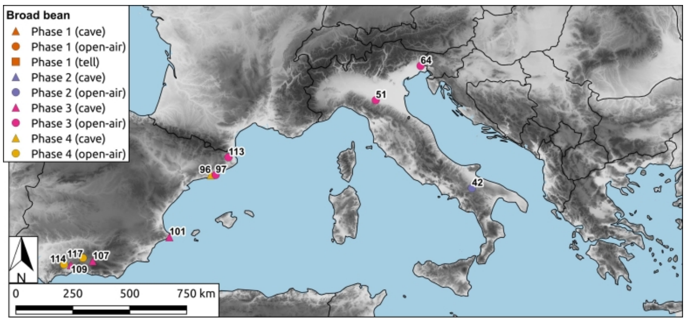


Figure11S: Distribution map of sites with broad bean (*Vicia faba*)

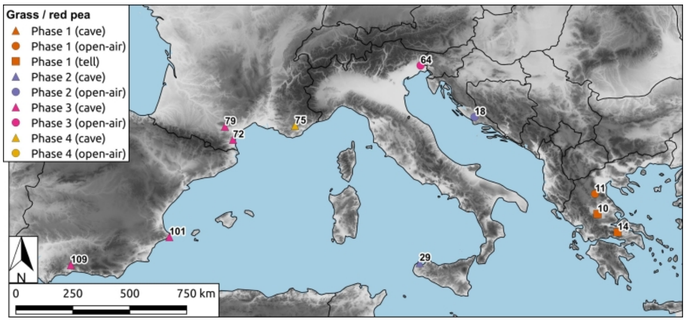


Figure 12S: Distribution map of sites with grass/red pea (*Lathyrus sativus/cicera*)

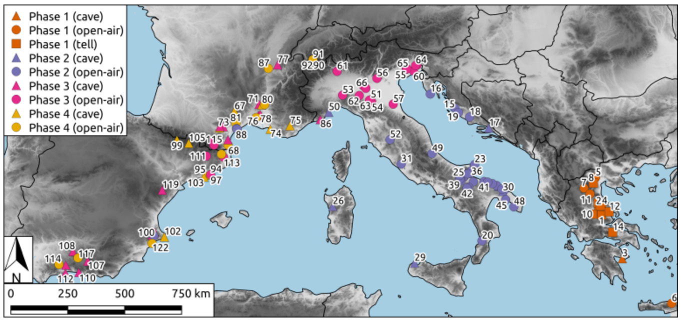


Figure 13S: Distribution map of all sites