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Long-term trends of land use and demography in Greece: a comparative study

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of human pressure on the Greek landscape through time. We demonstrate that SPDs offer a useful approach to outline differences between regions and a useful complement to archaeological site surveys, evaluated here especially for the onset of the Neolithic and for the Final Neolithic/Early Bronze Age transition. Pollen analyses highlight differences in vegetation between the two sub-regions, but also several parallel changes. The comparison of land cover dynamics between two sub-regions of Greece further demonstrates the significance of the bioclimatic conditions of core locations and that apparent oppositions between regions may in fact be two sides of the same coin in terms of socio-ecological trajectories. We also assess the balance between anthropogenic and climate-related impacts on vegetation and suggest that climatic variability was as an important factor for vegetation regrowth. Finally, our evidence suggests that the impact of humans on land cover is amplified from the Late Bronze Age onwards as more extensive herding and agricultural practices are introduced.

Long-term trends of land use and demography in Greece: a comparative study

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Abstract

This paper offers a comparative study of land use and demographic development in northern and southern Greece from the Neolithic to the Byzantine period. Results from summed probability densities (SPD) of archaeological radiocarbon dates and settlement numbers derived from archaeological site surveys are combined with results from cluster-based analysis of published pollen core assemblages to offer an integrated view of human pressure on the Greek landscape through time. We demonstrate that SPDs offer ~~can be~~ a useful approach to outline differences between regions and a useful complement to archaeological site ~~records~~surveys, evaluated here especially for the onset of the Neolithic and for the Final Neolithic/Early Bronze Age transition. Pollen analyse~~i~~s highlight differences in vegetation between the two sub-regions, but also several parallel changes. The comparison of land cover ~~changes~~ dynamics between two sub-regions of Greece further demonstrates the significance of the bioclimatic conditions of core locations and that apparent oppositions between regions may in fact be two sides of the same coin in terms of socio-ecological trajectories. We also assess the balance between anthropogenic and climate-related impacts on vegetation and suggest that climatic variability was as an important factor for vegetation regrowth. Finally, our evidence suggests that the impact of humans on land cover is amplified from the Late Bronze Age onwards as more extensive herding and agricultural practices are introduced.

Keywords

Land use; Land cover; Pollen; Archaeology; Summed Probability Densities; Greece

Introduction

Changing human population levels exhibit a close connection with human impacts on the landscape (Ellis et al., 2013; Hughes et al., 2018; Kok et al., 2016). Despite this general relationship, societal trajectories are often complicated, non-linear and imprinted in the archaeological, historical and environmental record in diverse ways. In order to make better sense of socio-ecological trajectories, we advocate multi-proxy approaches and interdisciplinary communication (Izdebski et al., 2016). This paper offers a regional case study drawing upon three main datasets from mainland Greece: archaeological radiocarbon dates, published fossil pollen core assemblages, and settlement evidence derived from archaeological field surveys (~~**Fig.**~~**Figure 1**). We use this information to compare and contrast the histories of northern and southern Greece respectively, from the Neolithic to the Byzantine period (86~~7~~50–746 BP; **Table 1;** all dates given as BP represent calibrated calendar years before present, where ‘present’ is defined as AD 1950). The compilation and combined analysis of the radiocarbon dates is the first ever published for Greek material, and while palynology has a longer research history in the region, its scale of aggregation here is a further novel contribution. The compilation of settlement data from the Peloponnese and Macedonia also provides fresh insight both about the particularities of each sub-region and about consistencies visible across Greece as a whole.

Table 1. Approximate absolute chronology used in the present paper for the study region as a whole, with the associated relative cultural phases and their abbreviations used in the text. All dates are means and all dates given as BP are calibrated calendar years before present (where ‘present’ is defined as AD 1950). The transitional period marks a period of high uncertainty within the established absolute and relative chronology (see further discussion in the text). The dates from 480 BC and later are mainly based on historical sources, while earlier dates rely primarily on radiocarbon evidence. Available radiocarbon dates suggest discrepancies between the two sub-regions for the earlier periods, the major of which are outlined in footnotes. For regional details see also Arvaniti and Maniatis, 2018; Cavanagh et al., 2016; Maniatis, 2014; Manning, 2010; Mee et al., 2014; Perlès, 2001).

Time (BP)	Time (BC/AD)	Cultural period

746–490 BP	AD 1204–1460	Byzantine and Frankish
1309–746 BP	AD 641–1204	Byzantine/Medieval
1650–1309 BP	AD 324–641	Late Roman/early Byzantine
1981–1650 BP	31 BC–AD 324	Roman (early and middle)
2273–1981 BP	323–31[1] BC	Hellenistic
2430–2273 BP	480–323 BC	Classical
2650–2430 BP	700–480 BC	Archaic
3000–2650 BP	1050–700 BC	Early Iron Age (EIA)
3600–3000 BP	1650[2]–1050 BC	Late Helladic (LH) or LBA
3950–3600 BP	2000[3]–1650	Middle Helladic (MH) or MBA
5150–3950 BP	3200–2000 BC	Early Helladic (EH) or EBA
5950–5250/4950 BP	*4000[4]–3300/3000 BC*	*Transitional period (FN/EBA), 'missing millennium'*
6450–5150 BP	4500–3200 BC	Final Neolithic (FN)
7450-6450 BP	5500–4500 BC	Late Neolithic (LN)
7950–7450 BP	6000–5500 BC	Middle Neolithic (MN)
8650–7950 BP	6700[5]–6000 BC	Initial (IN) and Early Neolithic (EN)

[Insert **Table 1** about here]

Study areas

The division of Greece into two sub-regions that we use here primarily follows bioclimatic criteria but also corresponds broadly to a well-known cultural division. The northern sub-region covers Thessaly and western/central Macedonia, and the southern sub-region primarily Boeotia, Attica and the Peloponnese, with southern Thessaly and the Spercheios river valley constituting a

[1] This year can also be set to 146 BC for the south, based on year for the Roman sack of the city of Corinth.
[2] This is a highly disputed transition, see Bietak, 2003; Lindblom and Manning, 2011; Manning, 2007.
[3] This date is a compromise between earlier dates in the south (~2150 BC) and later ones in the north (~1900 BC) (Arvaniti and Maniatis, 2018; Cavanagh et al., 2016; Maniatis, 2014).
[4] Very few radiocarbon dates have been confirmed for this period. Isolated dates suggesting an earlier start for EH are available from Mikrothives in Thessaly (5450 BP/3500 BC) and at Aghios Ioannis in Thasos (5550 BP/3600 BC) (Arvaniti and Maniatis, 2018). A confirmed late end date for the FN (~5650 BP/3700 BC) is present from Aghios Antonios Potos in Thasos where two dates show FN occupation within the 4th millennium (Maniatis et al., 2015).
[5] This date is a compromise between earlier dates in the south (~6800 BC: Perlès, 2001) and later ones in the north (~6600 BC: Maniatis, 2014).

~~border zone between them. Eastern Macedonia and Thrace, as well as Crete and the Cycladic island sphere have not been considered as part of our core case studies, primarily because of the absence of suitable overlap between datasets, but are nevertheless incorporated as important reference points, especially for the radiocarbon densities.~~

The climate of Greece exhibits transitional characteristics, with vegetation zone characteristics ranging from thermo-Mediterranean to meso-Mediterranean with even supra-Mediterranean (continental) conditions in some areas (~~**Fig.**~~**Figure 1b**; for a definition of the vegetation zones, see Luterbacher et al., 2012; Quézel and Médail, 2003)~~Luterbacher et al., 2012)~~, driven mainly by significant differences in the distribution of temperature and precipitation. The highly variable physiography of the Balkan peninsula adds further marked dissimilarities between not only the north and the south of Greece but also between the west and east coasts, or the plains and the mountains (Maheras and Anagnostopoulou, 2003; Xoplaki et al., 2000: 133–137)~~(Maheras and Anagnostopoulou, 2003; Xoplaki et al., 2000: 5–9)~~. Precipitation primarily falls during winter and is mostly associated with eastward tracking cyclones. This eastward transport of moist air in combination with a north-south trending mountain range results in overall wetter conditions in western Greece and more arid conditions in eastern Greece. In addition, latitudinal differences lead to generally cooler conditions in the north versus the south.

For the present study, the northern sub-region covers primarily Thessaly as well as western and central Macedonia, and the southern sub-region is constituted by Boeotia, Attica and the Peloponnese. The division allows good overlap between available radiocarbon dates, pollen assemblages and site data and facilitates comparisons between datasets. Although no division is without grey-zones, this north-south division reflects general differences in bioclimatic conditions of the pollen cores (**Figure 1b**), a common division of archaeological and historical research and broad cultural-historical differences (e.g. Bintliff, 1997; Cline, 2010; Kotsakis, 2014). It would be useful to extend the geographical scope in the future, but Eastern Macedonia and Thrace as well as Crete and the Cycladic islands ~~sphere~~ have not been considered as part of our core case studies because of data limitations, ~~but~~although they are incorporated as important supplementary reference points, especially for the radiocarbon densities.

Even with our chosen division into northern and southern Greek case studies, inevitably the narrative offered below must adopt a ‘broader brush’ than most archaeological and historical research in the region, both in terms of spatial and temporal resolution. Greece is a highly fragmented landscape that tends ~~to~~ not to be suited to blanket analyses, with the effect that research is often compartmentalised into more detailed projects (e.g. Cline, 2010). Both of our chosen sub-regions lump a significant amount of variability, in terms of diverging societal trajectories as well as research emphasis. While the Neolithic “tell” societies have been a long-standing focus in the archaeology and the environmental sciences of northern Greece (Glais et al., 2016; Karkanas et al., 2011; Kotsakis, 1999), studies of Neolithic southern Greece are few, by comparison, with those of the Bronze Age and especially the Late Bronze Age (LBA) societies standing out. These circumstances are to large part reflective of broader biases in archaeological visibility, i.e. the prevalence of sites and their monumentality ~~and~~or ~~,~~ the varying diagnosticity of material culture across the different regions and periods. Methodological differences between regions can also be noted, such as a generally greater prevalence of archaeobotanical and archaeozoological analyses in the north (especially over the last 20 years, e.g. Nitsch et al., 2017; Valamoti, 2004), in contrast to the emphasis on intensive archaeological field surveys in the south (Alcock and Cherry, 2004)~~(Alcock and Cherry, 2004a)~~. An important focus in the north has furthermore been on the social landscape of individual settlements (see reviews by Andreou, 2010; Kotsakis, 2014). In contrast, there has been a rising number of human-environmental analyses ~~during~~ over the last 5-10 years in both sub-regions, constituting an expanding body of research into social-ecological trajectories across Greece (e.g. Izdebski et al., 2016; Lespez et al., 2016; Weiberg et al., 2016)~~(Weiberg et al., 2016)~~.

Material and methods

Radiocarbon ~~method~~summed probability distributions

Aggregate sets of radiocarbon dates have become an important, high temporal resolution proxy for changing levels of human activity over time, despite continuing fierce debate about the biases they might carry with them (Palmisano et al., 2017; Timpson et al., 2014). We have extracted lists of Greek dates from Reingruber and Thissen (2005), Weninger (2017: CALPAL)~~Weninger et al. (2009: CALPAL)~~, Hinz et al. (2012: RADON), Manning et al. (2015: EUROEVOL), Brami and Zanotti (2015), CDRC (2016: Banadora), the 14SEA Project (Reingruber and Thissen, 2016), and the ORAU date lists (2016). For the vast majority of samples, Wwe have furthermore used the original publications to find new dates or check, enhance and georeference those already listed by others. For this paper, we sum the radiocarbon probability distributions of individual dates (known hereafter as summed probability distributions or SPDs) and anticipate that higher sums will indicate, on average, more human activity (and hence by inference probably higher population) in a given period of time. Where there are higher levels of radiocarbon sampling for certain chronological phases and/or certain sites (e.g. due to biases in research interests), these can be addressed by grouping dates within a few years of each other (for this paper, those within 50 uncalibrated years of each other from the same site) and re-scaling the result by the number of dates (before summing for all sites). In our case, across all of Greece for instance, 2143 dates have been summed across 210 sites into 1074 site bins (Fig.**Figure** **1a** **and Supplementary Table 1**), excluding those dates that exhibit poorly understood reservoir effects (e.g. all shells) or that do not have plausible anthropogenic causes (e.g. most dates from environmental cores/profiles).

Following previous work (Weninger et al., 2015) demonstrating that normalised calibrated dates can produce abrupt, artificial peaks in SPDs at steep portions of the radiocarbon calibration curve (particularly late Pleistocene/earlier Holocene time series, e.g. Roberts et al., 2018; note that throughout we have used IntCal13, Reimer et al., 2013), we have preferred to sum unnormalised distributions, but note that the conclusions remain broadly the same if normalised dates were used. In order to test these radiocarbon SPDs for meaningful departure from what we might expect by chance, two complementary approaches are (a) to compare the observed SPD to with conditional-random sets of thoseof hypothetical dates produced by according to a theoretical null model of population change (Bevan and Crema, 2018(Crema and Bevan, 2018: modelTest, 'uncalsample'"help(modelTest")); for the original approach and slightly different implementations, see Shennan et al., 2013; Timpson et al., 2014), or (b) to compare the SPD of a sub-set of dated samples (e.g. from a geographical sub-region A) and withto a simulated set of random dates drawn either from a second sub-set or the entire parent set (e.g. either region B or all regions in the dataset, see Crema et al., 2016)Crema et al. 2016). In the first case, we fit a theoretical model of demographic change (exponential in this case, but alternatively logistic or uniform, for example) to the observed data on the calendar scale (adjusting for the assumption of a uniform distribution: Bevan and Crema 2018: modelTest),~~,~~ then back-calibrate the expected population intensity before simulating a set of conventional radiocarbon ages (equal to the number of observed dates) proportional to the resulting per-^{14}C year amplitude. These hypothetical samples are then calibrated and summed. The same process is repeated many times (e.g. 1000) to provide a global goodness-of-fit test and 95% critical envelope. In the second case, we hold constant the measured age of the observed samples, but simply shuffle the label identifying which geographic region the sample comes from.

[Insert **Figure 1** about here]

Pollen assemblages and cluster analysis

The pollen count data used in this study were obtained from the European modern (Davis et al., 2013)~~(Davis et al., 2013)~~ and fossil pollen databases (EPD version: Oct. 2017: Leydet, 2007-2017). Descriptions of the methodological approaches developed and applied to the pollen datasets is provided ~~in~~ by Woodbridge et al. (2018)~~Woodbridge et al. (in press)~~ and Fyfe et al. (2018). Pollen sequences with reliable chronologies (Giesecke et al., 2014) were selected for analysis. The pollen count data from each site were summed into 200-year time windows and analyses were applied to the entire Mediterranean region (Roberts et al., this volume) in order to identify key vegetation types. Analyses for a sub-set of 334 pollen assemblages are presented in this paper, divided into the north (21~~0~~ sequences~~sites~~) and south sub-regions (12~~0~~ sequences~~sites~~) across 28~~30~~ sites (~~Fig.~~**Figure 1b** and **Supplementary ~~SI~~ Table 2~~1~~**).

An unsupervised data-driven approach was used to assign pollen samples to vegetation cluster groups based on the similarity of their taxa assemblages using Ward's hierarchical agglomerative clustering method (Ward, 1963) within the rioja R package (Juggins, 2015), ~~2015)~~ (see Woodbridge et al., 2018~~Woodbridge et al., in press~~, for a detailed description of the cluster analysis approach developed). The frequent and abundant pollen taxa were identified within each cluster group based on the median and interquartile range (IQR) of each taxon. Interpretive name descriptors were given to each vegetation cluster (see Woodbridge et al., 2018, for a discussion of the assigning of name descriptors)~~(see Woodbridge et al., in press, for a discussion of the assigning of name descriptors)~~. Vegetation cluster group changes were calculated as an average for all sites in Greece and within each sub-region and plotted stratigraphically. Analyses comprise t~~T~~he -average a~~A~~rboreal p~~P~~ollen sum (AP~~%~~), a sum of tree crop indicators (OJC: ~~(~~*Olea*, *Juglans, Castanea*) (Mercuri et al., ~~Mazzanti, Florenzano, Montecchi and Rattighieri,~~ 2013a), calculation of an anthropogenic pollen index (API: *Artemisia, Centaurea*, Cichorieae ~~cichorieae~~ and *Plantago*, cereals, *Urtica* and *Trifolium* type) (Mercuri et al., ~~Mazzanti, Florenzano, Montecchi, Rattighieri, et al.,~~ 2013b), and a sum of pastoral indicators (Asteroideae, Cichori~~oid~~eae, *Cirsium*-type, *Galium*-type, Ranunculaceae and *Potentilla*-type pollen) (adapted from Mazier et al., 2006). An additional, regionally adapted~~, and a~~ pollen disturbance index ~~are~~ is used to explore pastoral activities in the Balkan peninsula (PDI: sum of *Centaurea*, Cichori~~oid~~eae, Plantago, *Ranunculus acris* type, *Polygonum aviculare* type, *Sarcopoterium*, *Urtica dioica* type and *Pteridium*) (Kouli, 2015). The taxon Oleaceae was grouped with *Olea* in the OJC index; within our dataset the few occurrences of Oleaceae are most likely to represent poorly-preserved *Olea*, and other taxa in the Oleaceae family are routinely identified separately (e.g. *Fraxinus*, *Phillyrea* or *Jasminum*). From here onwards~~forwards~~ this group is referred to as *Olea*. Juglandinae is grouped with *Juglans* in the OJC index. Juglandinae in pollen records from Greece include some sporadic (six in-total) grains of *Carya* or *Pterocarya* encountered in two of the pollen records, and thus are considered to represent *Juglans*.

Compilations of archaeological site data

Archaeological site data ~~was~~ were assembled for comparative purposes and ~~as~~ to test samples to evaluate population reconstructions based on the SPD results ~~**(Fig. 1b)**~~. In order to accomplish a good overlap between all records, the samples were chosen from within the SPD focal regions, which also correlate with the pollen locations (**Figure 1b**). Therefore, although archaeological survey data are available from the Cyclades as well as from Crete, their inclusion is~~are~~ beyond the scope of the present study. Within the sub-regions, we have aimed for similar-size and geographically coherent test samples with information from other regions used to complement discussions. Site data for the south wer~~e~~as collected from eight intensive archaeological surveys in the Peloponnese, totalling 598 sites (2558~~9~~ site phases and~~;~~ ~~**SI**~~ **Supplementary Table 3~~2~~**).[6]

[6] The surveys used for the southern region were collated as part of the Domesticated Landscapes of the Peloponnese (DoLP) project and ~~follow~~ cover the Neolithic to Roman ~~time frame~~ periods (6800 BC-AD 300) ~~and~~ as well as the NE to SW transect across the Peloponnese utilized for that project. The Laconia survey -is thus not included, nor are

Few intensive surveys have been conducted in the north and the archaeological dataset used for the sub-region is therefore a combination of moderately intensive and extremely extensive survey datasets, totalling 637562 sites (1372 1270 site phases; and **Supplementary I Table 32**). Although the number of sites is almost equal, the number of site phases (i.e. with each chronological phase at a site counted as one site phase) make evident the lower resolution generally produced by the extensive, non-systematic method in survey methods in Macedonia. These differences in resolution will inevitably effect the comparisons between the north and south and should therefore be kept in mind when interpreting the results.

For over a century, archaeological site surveys have provided significant new data on developing settlement structures. However, differences in field-based methods, ceramic visibility and site identification criteria can make comparisons between datasets and between periods complex and sometimes problematic (Alcock and Cherry, 2004; Bintliff and Sbonias, 1999; Palmisano et al., 2017)(Alcock and Cherry, 2004b; Bintliff and Sbonias, 1999; Palmisano et al., 2017). Major points of concern for the present paper are the level of certainty of the assignment of a site to a specific period, variation in site sizes across time, the contemporaneousness of sites assigned to a period of long duration (e.g. the EH II period: 4850–4150 BP), and different chronological distinctions used by individual researchers. These issues are probably further exaggerated by the fact that most of the data for the south derive from fully published intensive surveys, while the Macedonian data derive to a large extent from non-systematic surveys, summarily or preliminarily published. In order to address these issues, we present three perspectives on the site data from the sub-region using methods presented in more detail by Palmisano et al (2017). Firstly, if we assign a relative confidence between 0 and 1 to each site that expressing our confidence that it belongs to a particular period, we can calculate at least three different 'counts'. This includes a maximal version ignoring any uncertainties in our dating and counting all possible sites, a minimal version counting only sites that definitely are in use, and a compromise approach that weights the count by a confidence value assigned to whether the site really has activity in that period. Secondly, information on site sizes are illustrated using the same three

any from the central or eastern Greek mainland. Other Peloponnesian intensive surveys are not included due to lack of published high-resolution data.

uncertainty levels. As a final guide, we calculate the aoristic sum of the overall site data in which each site's contribution to the overall count is decided by the length of the timespan of the relative chronological period to which a site has been assigned.

Results

Radiocarbon

The SPD presented here is the first region-wide assessment assembled for Greece, although regional models for the north, south and the islands have been attempted (Arvaniti and Maniatis, 2018). A preliminary caveat to note is that, while the overall sample of archaeological radiocarbon dates is adequate for attempting the kind of population modelling offered here, it is by no means as substantial as the data available in other regions (e.g. north-west Europe: Bevan et al., 2017). There are also far fewer dates covering the period after about ~2500 BP, largely because there is no strong academic tradition of collecting radiocarbon dates to address Classical Greek to modern research questions. We therefore restrict our use of aggregated radiocarbon dates as a population proxy to ~~only this later~~the Mesolithic-EIA timespan and address trends in later periods via other means (primarily settlement surveys). The spatial distribution of the selected radiocarbon dates overlaps well with the two focal regions identified for pollen core characterization. Beyond this we have included dates in Thrace and in the south Aegean respectively both for comparative purposes and to retain as large a sample as possible (~~**Fig.**~~**Figure 1**, especially the distinction between 'focal' dates that overlap with the pollen diagrams and 'others' beyond this area). It is worth noting that while there might be slight imbalances in the relative emphasis placed on sampling absolute dates for, say, 9000–5000 BP versus 5000–3000 BP in each sub-region, and also between sub-regions (cf. Arvaniti and Maniatis, 2018, and **Supplementary Table 1**), overall the sample sizes are similar and cautious comparison remains useful.~~,~~

[Insert **Figure 2** about here**]**

Figure 2a presents the resulting summed probability distribution (SPD) of archaeological radiocarbon dates for ~~all of~~ both the north and south regions of mainland Greece with each date normalised prior to summation while ~~**f**~~**Figure 2b** provides the same result when dates are left unnormalised. Both approaches produce broadly similar results, although we hereafter focus on the latter for reasons noted above. **Figure 2b** also summarises the main chronological divisions used in Greece, as derived partly from radiocarbon dates and partly from relative dating of artefact types (especially pottery styles and lithic traditions) (Bintliff, 2012; Finné and Weiberg, 2018; Manning, 2010). As a first guide to where certain portions of the overall time series depart from baseline expectations, we have fitted an exponential model of population growth (~~**Fig.**~~**Figure 2c**), and simulated conditional random date sets from this model (with the same sample size as the observed data) to produce a 95% critical envelope, above or below which to assess deviations in the observed data.

What is striking is that the radiocarbon proxy broadly matches the narrative of cultural change traditionally offered for this region, with the EN starting ~8750 BP but growing more substantial in character during the following centuries and then a plateau in growth by the MN period. The LN–FN phase (aka Chalcolithic) in Greece spans a couple of millennia and suffers from many alternative chronological schemes (with regional variations, e.g. Nowicki, 2014; Tsirtsoni, 2016b)~~(Nowicki, 2014; Tsirtsoni, 2016b)~~, and the overall SPD suggests two or three distinct peak episodes within these later Neolithic phases and a decline during FN (***see further below***). An inferred boom in population sometime ~4750 BP makes archaeological sense in terms of observed moves in certain regions towards more complex cultural behaviour (e.g. EH II in the Peloponnese, Kampos/Keros-Syros in the Cyclades, Early Minoan I late/Early Minoan IIA in Crete, see, e.g. Cline, 2010, for an overview). By approximately ~4350 BP, the time series suggests a downward demographic trend again which is in line with wider Aegean and eastern Mediterranean evidence for major disruption in the last centuries of the Early Bronze Age (EBA) (Dalfes et al., 1997; Jung et al., 2015; Maran, 1998; see also Arvaniti and Maniatis, 2018, ~~and~~ for the possible differences regarding the timing of the EBA II/III and EBA/MBA transitions in the north, south and the Cyclades). During the Middle Bronze Age (MBA) and LBA (from ~4000 BP) we then see recovery followed by substantial inferred growth, consistent with the archaeological observation that this period saw the emergence of the first 'Minoan' palaces and more complex political formations on Crete (Whitelaw, 2012). An inferred decline phase at the very end of the Bronze Age is also consistent with existing archaeological interpretation of this period as being one of political and demographic collapse, followed by profound social transformation (Knapp and Manning, 2016).

While the current sample size prevents us from considering lots of small sub-regional patterns, further insight is possible if we simply split the radiocarbon data from north to south. **Figure 3a** shows the resulting SPD both for the northern focal region that overlaps with our selected pollen evidence, as well as the SPD produced from the slightly wider northern area shown in **Ffigure 1**. Both patterns are reassuringly similar. **Figure 3b** does the same for focal and wider southern regions, and here there is slightly more discrepancy particular in the second millennium BC, where the addition of Cretan and other southern Aegean dates suggests a much 'sharper' pattern —--of two dramatic growth phases separated by a decline ~4200–4000 BP —--than when the Peloponnese focal region is just treated aloneon its own.

[Insert **Figure 3** about here.]

Figure 3c allows a more robust comparison of north and south by depicting the wider northern region and then the critical envelope produced by a permutation test of the region labels. Thus, when the brown line representing the observed SPD falls above the grey envelope it suggests the north is doing better demographically than the south, and more precisely, better than we would expect by chance all regions being equal. In contrast, where it drops below the grey envelope, the south can be suggested to be doing demographically better. The positive northern deviation 8450–7750 BP corresponds very well to substantial tell formation during this EN phase across Thessaly especially (Reingruber et al., 2017). The negative deviations during late EH II (~4450-4250 BP) and MB II–LB II (~3850-3350 BP) respectively correspond to well-known rises in complexity that are far more visible in the south (***see above***). Both north and south are also consistent in exhibiting dips in inferred population 6000–5000 BP and then again at ~3000 BP.

Site Surveys

As a complement and/or corrective to radiocarbon evidence, a compilation of archaeological site datasets for Macedonia and the Peloponnese enables a quantitative comparison of the regional settlement trends at a scale not attempted before for Greece. Note, however, that these samples do not represent the ~~whole~~entirety of settlement in these sub-regions and that ~~intra-regional~~ variations within these sub-regions are ~~ample~~likely to be non-trivial. ~~that~~ It should also be kept in mind that although our time series changes abruptly in places~~,~~ this is ~~largely~~partly due to the periodisation used by archaeologists. This system of periodisation ~~(which~~ is both a practical convenience and a reflection of our ability to systematically find chronological patterns in assemblages of past material culture such as pottery and lithic traditions, which will inevitably give a picture of abruptness for demographic processes that in reality would have been ~~much slower working and gradual~~more gradual or abrupt in ways that do not exactly match ceramic styles~~)~~. As an initial view of the number of sites identified in the two sub-regions, **Figures 4a** and **5a** give the raw count of recognized sites for the two regions. The comparison underlines the greater number of Neolithic and especially MN–LN sites in Macedonia, compared to the Peloponnese, which is in line with the high SPD for the Neolithic north. The FN period ~~(6500-5200 BP)~~ constitutes a clear low point in Macedonia while showing a definite increase in~~of~~ sites in the Peloponnese. The EBA represents a high-point ~~n apex~~ in terms of site number in both regions, on par with the LN in the north ~~and exceeded by no other period in the north and only by the Classical-Hellenistic period (2430–2096 BP) in the south~~. After a subsequent drop in the late EBA in the south and with the onset of MBA in ~~both regions~~the north, site numbers increase again for the LBA. T~~t~~he trajectories of the two sub-regions diverge thereafter, with an immediate high- for ~~LBA~~ Macedonia in the LBA (from ~3600 BP), followed by ~~slow decline~~ more or less upheld site numbers during ~~in~~ the EIA and historical~~subsequent~~ periods. On the Peloponnese, instead, ~~the continued Bronze Age is signified by fluctuating site numbers,~~high site numbers in the LBA are followed by a low point in the EIA and a gradual build-up towards an overall ~~high~~ apex in the Classical–~~early~~ Hellenistic period. The summing up of total estimated site area for each year of the time series (~~**Figs.**~~**Figures** **4b** and **5b**) brings a slightly different picture and enables a discussion on the role of site nucleation during the same time periods, i.e. the addition of larger sites suggesting that more people congregated in these settlements. For the Peloponnese, the evidence especially points to the palatial Bronze Age and the period from the EIA (~2700 BP) onwards, while for Macedonia the greatest difference can be seen for the MN–LN period (comparing the information in ~~**fig.**~~**Figure** **4a-b** and ~~**fig.**~~**Figure** **5a-b**). Although the latter could be used to pinpoint the large size of some tells and sites of the flat-extended type, it should also be remembered that size designations for Macedonia are less reliable and that flat extended sites may very well have been quite sparsely populated.

[Insert **Figures 4-5** about here]

An important note for Macedonia site numbers is also that many of the surveys ~~had a~~ focus<u>ed</u> on prehistory (see **<u>Supplementary</u>** ~~**SI**~~ **Table** <u>**3**</u>~~**2**~~), suggesting that both size and the number of historical periods is underrepresented (cf. Andreou and Kotsakis, 1999). The aoristic approach is therefore a useful corrective as it down-weights periods where sites are only allocated to very long timespans (where we might suspect that in fact site durations were shorter but just hard to notice). A notable result in both regions is a much-reduced amplitude of sites for the Neolithic and the EBA where the chronological range for a given site can span more than a millennium <u>**(Table 1)**</u>. Conversely, the aoristic sum shows significantly increased peaks <u>during the Mycenaean palatial period (3350–3150 BP)</u> ~~in the LH III~~ and ~~late~~ Classical<u>–</u>~~-early~~ Hellenistic periods in the Peloponnese relative to the same periods in **<u>F</u>~~f~~igures 5a–b.** However, since the aoristic method deflates (inflates) counts for periods with wide (narrow) date ranges, over-estimations are likely to occur, such as the peak in EIA Macedonia. The latter nevertheless serves to pinpoint that the EIA may have constituted less of a break in Macedonia than generally assumed for the Peloponnese (Koukouli-Chryssanthaki, 2014).

Pollen

A complex pattern of decreasing deciduous oak woods<u> (cluster 6.1)</u> does broadly correlate (negatively) with the rising population numbers inferred by the SPD and archaeological site data, signalling an opening of the oak wooded areas and hence a landscape increasingly affected by human activities. There are, however, substantial differences between the two sub-regions. Forested and wooded areas are more dominant and more diverse in the north (including for example alder woods<u>, cluster 8.1,</u> from <u>~</u>52<u>0</u>~~5~~0 BP, not at all represented in the south). Deciduous oak parkland (<u>c</u>~~C~~luster 6.2) is also more predominant in the north, while pasture/wetland (<u>c</u>~~C~~luster 3.0) is ubiquitous in the south<u> **(Figure 6)**</u>. Significant differences between the two sub-regions can also be found in all human indicator groups (OJC, API, PDI). The API indicator group for the north displays notably lower levels than in the south (~~**Fig.**~~<u>**Figure**</u>

7), apart from in the very earliest samples (consisting mostly of deciduous oak parklands, typical in northern Greece before the establishment of the deciduous oak woodlands, see e.g.Willis, 1994), as well as towards the present time. A trend of slowly increasing API levels from ~3500 BP can be noted in the north, which is in some sense paralleled in the south from ~4500 BP. Overall, however, records from the south display fluctuating but continuously high API levels. There is, however, a very distinct drop in all pollen indicator groups in the south between 2000 and 1000 BP. In the north, this occurs later and is mainly visible in OJC (especially *Juglans*) and only to a smaller degree in the PDI and API.

[Insert **Figure 6** about here.]

[Insert **Figure 7** about here.]

These results highlight the different geographical settings of the pollen cores in the two sub-regions of our study, predominantly in terms of the bioclimatic zones where the pollen core locations are situated. The sites for the north are all but twoone from within the meso-Mediterranaean and supra-Mediterranean zones, and all but three are located at medium and high elevation (>260 masl), while all samples for the south derive from the thermos-Mediterranean zone, being and all but one are located at low elevations (most around 20 masl) (**Fig.Figure 1b, Supplementary Table 2**). The differences in the API can also (to some extent) be associated with the fact that many most of the core locations in the north come from regionsdo not have any major settlements within their catchments some distance away from major settlements, (with the exception of the Orestias core that clearly records activity from the nearby settlement of Dispilió, with increased human activity during Neolithic, Hellenistic and Roman times , see (Kouli, 2015; Kouli et al., 2018; Mercuri et al., in press)Kouli, 2015; Kouli et al., 2018; Mercuri et al., this issue). In contrast, most pollen core locations in the south are within regions for which archaeological remains suggest high human activity (if not specifically on site). The coastal locations of the cores mean moreover that they are also closer to the conditions where taxa included in the API grow naturally.

Apart from these differences, there are also some interesting trends that are roughly similar between the sub-regions. There is a clear peak in deciduous oak woods (cluster 6.1) around 6000–5400 BP in the north, and 7000–6000 BP in the south, decreasing thereafter until ~40~~5~~00 BP in both sub-regions (i.e. a trend of decreasing values spanning from FN through to mid-EBA), followed by an (almost) gap in deciduous oak woods, with an overall emphasis on ~~the last six hundred years (~~4000–3400 BP (~~,~~ see ~~**Fig.**~~**Figure 6**). This 600-year long period corresponds to the beginning of the Middle Helladic period until the beginning of the Mycenaean palatial period in the southern Aegean and would have meant a decimation of deciduous oak woods but without resulting in any significant change in ~~the sum of arboreal pollen (~~AP~~%)~~. Another similarity between the sub-regions can be found in the timing of the peak period for OJC from ~3000 to 2000 BP in the south and 2750–1750 BP in the north (**see further below**). The percentages of OJC, however, are higher overall in the south compared to the north.~~, however, and t~~The OJC index in the south does furthermore ~~is~~ mainly consists~~ing~~ of *Olea*, and these high values correlate well with low values of deciduous oak woods. In the north, where our sites are mostly located outside the olive distribution zone, *Olea* constitutes a very minor part of OJC (if any), which is instead primarily made up of walnut (*Juglans*) and correlates well with high values in the deciduous oak woods (e.g. ~2500–1500 BP). The only exception ~~in this~~ is the coastal site of Tristinika (Panajiotidis and Papadopoulou, 2016), a site within the thermo-Mediterranean climate zone and thus closer to the locations in the south in terms of vegetation.

Data Synthesis

Combining the lines of evidence provided by these three datasets is an important but challenging exercise. Although visual comparisons and qualitative assessments remain central, quantitative methods can help to nuance discussion. It is possible for instance to assess both when and to what degree two or more time series correlate well with one another. **Figure 8** provides an example of such a 'consensus model', seeking agreement between the ~~complete set of~~ radiocarbon dates from the ~~two~~ southern focal region~~s~~ presented in **F~~f~~igure 3a** and the ~~combined~~ number of Peloponnesian sites presented in **F~~f~~igure~~s 4–~~5**. In the model it is assumed that the shape of a site's activity (or its use-intensity) was not uniform across its sometimes large assigned date range, but instead was unevenly distributed roughly according to the varying activity suggested by the SPD. The *amount* the site then contributes to the overall summation is calculated as an average of how important that time range is to the radiocarbon (i.e. relative height of thehow high the line in 'focal south' time series in Ffigure 3b is for 6450–5050 BP compared to the rest of this series) versus how important it is in the survey evidence (i.e. the relative height of how high the line is the maximum 'surface area' from Ffigure 5b for 6450–5050 BP compared to the rest of this series). We certainly do not propose that this is a perfect final model of likely prehistoric population change in the Peloponnese, and as noted above, the very abrupt drops are largely an effect of our modern periodisation of time.. However, the overall patterns remain plausible and the exercise in consensus-building is useful, not least because it highlights that perceived problem periods of incompatibility in the evidence (such as FN–EB1: **see further below**) can sometimes be reconciled.

[Insert **Figure 8** about here]

Table 2. Spearman's Rank Correlation Coefficient (R-values) value matrix for the period 10000-2800 BP for northern and southern Greece and both regions combined. Statistical significance in bold values ($p<0.05$).

	^{14}C SPD		
	N	**S**	**All (N + S)**
AP sum	**-0.38**	-0.3	**-0.51**
Cerealia	0.11	-0.27	-0.15
OJC	0.28	**0.38**	0.23
Juglans	**0.35**	0	0.27
Olea	-0.09	**0.41**	0.16
API	**0.34**	0.19	**0.31**
Regional pastoral indicators	0.05	0.26	0.19
PDI	0.04	**0.42**	**0.51**
Cichorieae	**0.32**	0.3	**0.32**

Spearman's Rank correlations (**Table 2**) indicate that the demographic proxy (SPD of radiocarbon dated sites) is negatively correlated with changes in AP% for all both regions, which implies that when there are greater populations there are fewer trees. However, this correlation, which only statistically significant for the north, and all correlations listed in **Table 2** are generally low (< ±0.5) compared to other parts of the Mediterranean (see further analyses by Roberts et al., in press: Table 3), indicating that the analysed relationships are more complex in

Greece than in many other regions. As expected, Tthe pollen indicator groups, which are reflective of human land use, generally show positive correlations with SPD, meaning that their prevalence increases with the increasing population. The PDI shows the strongest significant positive correlation with SPD in the south and for all the sub-regions combinedregions, which suggests that when populations are larger, there is greater vegetation disturbance. However, Regional pastoral indicators do not show significant correlations, which may be because this indicator group derives from pollen sites in France (Mazier et al., 2006), and may be less relevant here. Overall, however, the SPD does seem to correlate better with the indicators of animal breeding (PDI), than with cultivation. This should be compared with results by Roberts et al. (in press) who single out tree cultivation indicators (OJC with the addition of *Vitis*) as the best pollen-based indicator of human activity in the Mediterranean basin. In mainland Greece, the correlation between SPD and OJC is only statistically significant in the south, but split on the components, *Juglans* is positively correlated with SPD in the north and for all regions combined*Olea* in the south, highlighting the different bioclimatic conditions of the sub-regions. SPD seems to correlate better with the indicators of animal breeding (PDI), than cultivation. The tree cultivation indicators (OJC) show a weak correlation with SPD although a difference in cultivation choices in the north (*Juglans*) is apparent. Although these patterns do seem to correspond with expected patterns, i.e. more people use greater areas of land for agriculture, the relatively weak correlations indicate again that in the drier parts of the Mediterranean especially, such as in (southern) Greece, are generally not strong (< ±0.5), which implies thatthe relationships between vegetation and population are complex over the long-term Holocene time frame (Roberts et al., in press).

Discussion

The results presented here so far provide a general overview of the trends highlighted by aggregating radiocarbon dates, synthesising pollen analyses, and combining site surveys for the Peloponnese and Macedonia. Throughout In the discussionthis final sectionIn the following discussion, we set out to integrate the three primary datasets and describe Greece's changing socio-ecological trajectories, with special emphasis on three periods and themes that have been prompted by the results in one or more of the datasets.

The onset of farming and Neolithic land use

Farming naturally brought major changes to land use and economic strategies in Greece. The lower SPD in the earliest Neolithic suggests a gradual emergence and demographic increase in farming communities that is consistent with archaeological information from both sub-regions. The dramatic rise ~8500 BP in the north represents the beginning of EN in Thessaly (Reingruber et al., 2017), but early radiocarbon dates also come ~~also~~ from Macedonia, ~~(~~especially from the Yannitsa plain (Maniatis, 2014; Maniatis et al., 2011). Many regions in the north, however, remain sparsely populated in the EN and in western~~W~~ Macedonia LN and/or FN sites clearly outnumber EN and/or MN sites (Andreou et al., 2001: 296–297) as also suggested by the site data from Macedonia (**~~Fig.~~Figure 4**). The same pattern can be noted for the south (**~~Fig.~~Figure 5**), with a low number of EN sites, increasing number and size during MN and a general expansion in site numbers in LN/~~early~~ FN. Comparing the two sub-regions, however, the SPD illustrates well the often noted and confirmed north–south demographic divide (Kotsakis, 2014; Mee, 2007), with overall smaller sites within larger territories in the south and larger and more densely placed sites in the north, likely resulting in an overall larger Neolithic population in the north. There is also a positive correlation between SPD for the north and ~~an in ie~~wetter climatic conditions around 8900–8300 BP, suggesting that the initial spread of farming was~~were~~ favoured by climate circumstances (Roberts et al., in press: 5b).

The results of the increased human pressure inferred from SPD and archaeological site data is not very clear in the pollen record, and it is possible to suggest that pollen archives often exhibit a local pattern characterised as ‘influence’ during the Neolithic, but then humans have a greater ‘impact’ during the Bronze Age (Mercuri et al., in press)~~(Mercuri et al., this issue)~~. This is in line with recent conclusions, based on anthracological data and other palaeoecological materials, that Neolithic communities in the north had only a local, modest effect on the surrounding landscape (Marinova and Ntinou, 2017; Ntinou, 2014). Nevertheless, the imprint of early human activities has~~ve~~ been evidenced in pollen records originating from sites close to ~~the~~ human activity centres already by the EN (Glais et al., 2016), becoming even more evident during the MN–LN (Glais et al., 2016; Kouli, 2015) in northern Greece. The overall AP~~%~~ remains nevertheless high in the Neolithic north, with possible troughs indicating more open landscapes in EN and LN, corresponding to low levels of deciduous oak woods ~8200 BP and ~6500 BP (**~~Fig.~~Figure 4b**), which may correlate with the effect of the initial EN expansion into the area and settlement diversification noted for LN/FN. On the whole, the LN period seems to be one of increasing site numbers and the colonisation of more marginal lands (Andreou et al., 2001). The EN setback in forest cover may also have been influenced by the 8.2 ka cold climate event (Gkouma and Karkanas, 2016; Kotthoff et al., 2008; Pross et al., 2009; Weninger et al., 2006, 2014).

-Evidence from the south is in partial contrast to this northern pattern, but ultimately the differences between them may be primarily due to the different locations of cores in the two regions (relative to vegetation zones and in extension to the intensity of human activity in the vicinity). AP% for the south suggests a notable opening of the landscape in the MN period (7500 BP) followed by a regeneration during LN (**Fig.Figure 7c**). The MN low point can perhapsconceivably be connected to the establishment of larger settlements in the coastal plains (and thus close to the core locations) (Cavanagh, 2004). The regeneration of the forest cover in combination with decreasing API and PDI values during LN indicate a change that perhaps can be seen as the result of a diversification of the settlement and/or herding patterns into areas further away from the coast (and hence further away from the pollen core locations). Isotopic evidence from LN Kouphovouno, SE Peloponnese, suggests shrinking herd sizes from MN to LN and more spatial diversity in grazing grounds (Vaiglova et al., 2014), which may lead to an overall diminished effect of pastoral activities to be recorded in the pollen records (cf. Halstead, 2000). It should also be borne in mind that the number of pollen sites in southern Greece prior to ~8000 BP is small (**Figure 6b**) and that reconstructed vegetation and land-cover changes in this sub-region during the EN must therefore be tentative.

Final Neolithic/Early Bronze Age

The transition to the Bronze Age, and specifically the period ~6500–5000 BP, has recently seen renewed attention (Dietz et al., 2018; Horejs and Mehofer, 2014; Tsirtsoni, 2016c). Special emphasis has been placed on the absolute chronology of the period but despite a concerted effort, very few radiocarbon dates have been found that cover the 'missing millennium', the FN/EBA transitional period from ~60005950—525300/5000 4950 BP (Maniatis et al., 2014) (**Table 1**). This pattern is supported in the north by the abandonment of many well-known Neolithic sites in the LN or early FN, such as Servia, Mandalo, Sitagroi and Dikili Tash (Andreou, 2010; Andreou et al., 2001; Maniatis and Kromer, 1990; Maniatis et al., 2011; Renfrew, 1971)~~(Andreou, 2010; Andreou et al., 2001; Maniatis et al., 2011; Maniatis and Kromer, 1990; Renfrew, 1971)~~. Conversely, some surveys in the south instead give evidence of increased numbers of sites (~~Fig.~~**Figure 5**; Bintliff and Sarri, 2018) and a second wave of colonisers moving into the Cycladic islands is also proposed for the LN–FN (Broodbank, 2000), suggesting perhaps an overall increase in activity, or at least in mobility (Parkinson et al., 2018). The long duration of the FN period (>1000 years), makes it probable, however, that the rise in site numbers suggested at first by southern surveys is much less significant than it appears or manifests in only part of the period, for example at its beginning and/or end (cf. the difference between **Figures 5a** and **5c**). The consensus model (~~Fig.~~**Figure 8)** downplays the amplitude of change but also still suggests that an overall drop in activity in the middle of the FN period is compatible with both survey and radiocarbon evidence once the chronological uncertainty of the former is taken into account (cf. Tsirtsoni, 2016a). The fact that sites dated FN/EBI are often detected in surveys and hence normally not radiocarbon dated nevertheless suggests that the inferred low population levels are to some extent a research bias. The abandonment of large sites may therefore signify a relocation of population in the landscape rather than a complete abandonment of regions, as exemplified by the site of Servia, where several smaller FN sites appeared nearby, only to be abandoned when Servia was reoccupied in the EBA (Andreou et al., 2001; cf. Alram-Stern, 2014; Tsirtsoni, 2016b). Furthermore, increased regionality noted for LN-FN pottery from the Peloponnese (Mee, 2007), in consort with settlement dispersal noted in both regions, signify a more fragmented and heterogeneous social landscape (Kotsakis, 2014). Such a landscape may result in a less visible archaeological record overall.

Interestingly, pollen evidence from both regions suggests a trend during the period towards decreasing values of deciduous oak wood from a ~6000 BP high point to a ~5250–5000 BP low point, suggesting, in contrast to the SPD, an increased overall human pressure on the landscape. ~~pollen evidence from both regions, suggests decreasing values of deciduous oak woods from a high point ?~6000 BP to a ~5250–5000 BP low point ?, which would be consistent with increased rather than decreased human pressure on this ecosystem.~~ The point of departure for this trend, however, is the result of a "closing" of the deciduous oak woods that would suggest decreasing human pressure during early FN. This peak is especially notable in northern Greece but represented also in the south by a 200-year period (from ~6200 BP). At the same time, both API and PDI levels show overall higher levels during this 'missing millennium' than just before and after (~~**Fig.**~~**Figure** **7**). This is especially notable in the pastoral indicators in the north, ~~and~~ while in the south, PDI~~, especially,~~ shows clearly increased values from ~6300 BP to ~5500 BP ~~in the south~~. High pastoral activity (PDI, and overall API) in the coastal Peloponnesian records could mean a change towards strategies in which the herds were kept closer to the settlements, regardless of location (cf. Valamoti, 2007). Also *Cerealia* show relatively high levels in both regions (with a peak just before 6000 BP in the north) and the levels remain higher during FN than in the preceding Neolithic phases. It should be noted, however, that the early *Cerealia* signal in the north is almost exclusively made up of~~by~~ samples from the Orestias record and likely signifies~~y~~ the intensity of cultivation in the lakeside settlement of Dispilió, settled from MN to EBA (Karkanas et al., 2011; Kouli, 2015). This circumstance highlights the local character of *Cerealia* pollen but also that it may be underrepresented in the overall northern record because coring locations tend to be away from archaeological sites (cf. Glais et al., 2016).

These results from pollen and archaeology during the FN (and early EBA) are clearly inconsistent and the evidence remains inconclusive. Indications for low inferred population coexist with relatively high values for anthropogenic pollen indicators, suggesting a complex pattern of human-environment dynamics. It should furthermore be noted that the period from 6000 to 5000 BP corresponds to a phase of enhanced aridity during the transitional period from the overall wetter conditions of the early Holocene to a generally drier situation in the Balkan region (~~**Fig.**~~**Figure** **6**; see also Finné et al., in press)~~Finné et al., this issue)~~. The~~is~~ period also overlap ~~concurs~~ with an interval of colder conditions recorded in the Aegean Sea (Rohling et al., 2002). This pattern clearly adds further complexities and such arid conditions may have had (long-term) effects on deciduous oak woods, for example. Climate change can therefore not be excluded as a partial driver behind noted vegetation changes, and possibly any associated cultural changes (Lespez et al., 2016; Roberts et al., in press)~~(Lespez et al., 2016)~~.

Variabilities in land use across time

One clear trend through time is an increasing scale and complexity of anthropogenic impact from the onset of the Neolithic until the present (Bintliff, 2012; Weiberg et al., 2016). In all accounts, for example, the Bronze Age represents a significantly more complex social structure (in the diversity of material culture and scale of supra-regional connectedness) and came with a much larger overall environmental footprint than the Neolithic. Although local demographic trends may not always follow this general trajectory (both small and large regions can be sparsely or densely populated regardless of wider trends), archaeological site data does nevertheless suggest a slow densification of settlements in the landscape through time (~~**Figs.**~~**Figures 4–5** and combined with SPD in ~~**Fig.**~~**Figure 3**). The effect of this trajectory is likely evidenced by~~in~~ the decrease in deciduous oak woods during the Neolithic and the continued low levels thereafter (~~**Fig.**~~**Figure 6**). Notably, this general trend for deciduous oaks closely follows the overall climate trend identified for the Balkan region with a long-term drying trend from ~8000 BP to ~3500 BP (~~**Fig.**~~**Figure 6;** also Finné et al., in press; cf. Roberts et al., in press)~~also Finné et al, this issue)~~. This is yet another indication that climate should not be disregarded as a partial driver for noted changes in vegetation. This long-term trend, however, is not linear. Significantly, the second half of the EBA constitutes an overall wetter period that may very well have been conducive ~~of~~ to the expanding settlement patterns during this period (Weiberg and Finné, 2013). The period ~4250–3500 BP, from the end of the EBA until early ~~the beginning of the~~ LBA ~~palatial era~~, constitutes an extreme low in deciduous oak woods in an otherwise continuous (albeit fluctuating) record of this vegetation type (cluster 6.1). This low is present in both regions and results in a relative increase in the visibility of pine woods (cluster 5.1) as well as deciduous oak parkland (cluster 6.2) and pasture/wetland (cluster 3.0). Pines, especially, are known to rapidly expand in disturbed areas (Bottema and Woldring, 1990; Kouli, 2012), and an increase of the taxon is common to several ~~Late~~ late Holocene pollen records from southern Greece (Jahns, 1993; Kouli et al., 2009; Triantaphyllou et al., 2010).

Interestingly, the SPD and site data diverge completely in both sub-regions 4250–3500 BP (~~**Figs.**~~**Figures 4–5**): while site numbers are increasing in the north, SPD is decreasing, and while site numbers are relatively low in the south, the SPD presents an all-time high. These marked contradictions require further examination.~~The archaeological data therefore remain inconclusive.~~ Moreover, the initial phase of the period ~4250–3500 BP corresponds to a period of dry climate conditions in the eastern Mediterranean region in general, including the so-called 4.2 ka event (Zanchetta et al., 2016), and to local evidence of dry conditions recorded in a speleothem stable isotope record from the Mavri Trypa Cave, ~~the~~ SW Peloponnese (Finné et al., 2017). Additionally, a N–S time-~~-~~transgressive aridification gradient, correlated to the 4.2 ka event, has also been recorded in the Aegean Sea (Triantaphyllou et al., 2014). Such dry conditions could clearly have been unfavourable for oak wood regeneration. Furthermore, the subsequent partial regeneration of the deciduous oak woods (from ~3500BP) corresponds in time with the probable expansion of population and overall activities in the landscape by the onset of the Mycenaean palatial era and suggests that anthropogenic factors may not have been the main driver behind the changes in the oak woods at that time. Although the average Balkan ~~z-score mean~~climate trend suggests dry conditions during LH III (3350–3000~~25~~ BP, see Finné et al., in press)~~)~~, the Mavri Trypa record, also included in the calculations of the average Balkan trend, indicates overall wetter conditions during the Mycenaean palatial period~~Mavri Trypa record indicate overall wetter conditions during the Mycenaean palatial period~~ (Finné et al., 2017; cf. Weiberg et al., 2016). This indicates local variability between the N and S part of the Balkan region and the results ~~,~~ suggest~~ing~~, like for the EBA, that expanding settlement patterns and overall economic wellbeing in southern Greece may have been supported by benign climate conditions ~~(Finné et~~ (Weiberg and Finné, 2018~~al, 2017; Weiberg and Finné, in press~~; cf. Roberts et al., in press)~~)~~.

Increased anthropogenic (API, PDI, ~~**Fig.**~~**Figure 7**) indicators are recorded from the LBA in both sub-regions, although more subdued in the north, and suggest economic expansion in line with an increased number of sites and inferred population growth. The first evidence for extensive agricultural and herding strategies has ~~are~~ also been identified during the LBA (Halstead, 1999; Nakassis et al., 2011), which from then on would to varying degrees have constituted a complement to small-scale mixed and more intensively practised agriculture (Halstead, 2000). Although environmental effects of small-scale mixed farming may very well be recorded by nearby pollen cores (Glais et al., 2016), extensive strategies -- in effect larger fields and herds -- are more likely to have large-scale effects on the palynological record (Halstead, 2000). Indicatively, the LH III period and especially the early phases of the historical period (from ~3000 BP) stand out as a watershed for the pollen-based anthropogenic indices in the pollen records and signify an overall change in~~of~~ the scale of land use in Greece. In both ~~regions~~regions, pasture/wetland (cluster 3.0) initially reached a low point (~3200–2200 BP) and thereafter gradually increased until early modern times (~~**Fig.**~~**Figure 6**). This change did not develop similarly in the two regions, but rather more strongly in the south (at the expense of sclerophyllous parkland, cluster 1.1) and accentuated in the north only after ~1700 BP (corresponding to a drop in deciduous oaks). It should be noted also that this cluster combines two different ecosystems (upland pasture and shallow marshy wetlands) and its fluctuating valuesons should be interpreted with caution and in combination with other indices.

In the south, then, low values of pasture/wWetland (cluster 3.3) correspond to a period of high API values that continue from LH III with a double peak ~3300 and 2300 BP, with PDI following the same pattern and both mainly driven by high values of chicory (Cichorioideae: **Figure 7**). OJC exhibits a very profound increase from ~3000 BP and a sharp fall after ~2000 BP following the curve of *Olea*. Deciduous oOak woods begin to regenerate from ~3500 BP, but a stronger signal (and an overall peak in AP%) is evident from ~2000 BP. This intensification of the signal coincides with a distinct drop in OJC, API, and PDI. The double API peak then coincides with the high point in site numbers during LH III and during the Archaic to early Hellenistic periods (**Fig.Figure 5**). Notably, the peak during LH III is driven by pastoral indicators, while in the historical period peaks are made up of both pastoral indicators as well as OJC (and especially *Olea*). The pollen record does therefore does clearlywellseems to reflect the LH III focus on cereal cultivation and pastoral activities, with large herds of sheep geared at supplying wool to the palatially controlled textile industry (e.g. Killen, 1984). In contrast, the levels of *Cerealia* instead decline thereafter until a ~2500 BP low (**Fig.Figure 7**). It is therefore probable that an increasing population in the south during the early historical periods was engaging more actively in olive cultivation (based on the rise in OJC) and pastoral activities (based on high values of Cichorioideae), and covered more of their cereal needs by importing grain from abroad (for a discussion of the significance of grain imports in this period, see Bresson, 2016; for evidence on Archaic to Hellenistic olive cultivation, see Foxhall, 2007). Aridity could potentially have been conducive of this change in strategies, with olive cultivation and herding being more sustainable during the accentuated dry conditions in the south ~3150–2450 BP (Finné et al., 2017; Norström et al., 2018; Weiberg et al., 2016). The Balkan climate records suggest that Cclimate conditions improved after ~2500 BP (**Fig.Figure 6**; with notable variability within the region, see Finné et al., in press)Finné et al, this issue) and it appears that the most extensive use of the landscape in Classical and early Hellenistic times had the benefit of wetter conditions. From ~1300 BP (AD 650), however, a new trend towards drier conditions was initiated, ~~and~~ continuinges ~~ges~~ until the modern day. The drop in anthropogenic indicators and the regeneration of the oak woods ~2000–800 BP in the south corresponds to the Roman and early Byzantine periods. The Roman period especially is known for large-scale economic reorganisations with large agricultural estates generally replacing the earlier dispersed pattern of small settlements and farmsteads spread across the landscape as a complement to *polis* centres (Alcock, 1993; Bintliff, 2013; Rizakis, 2013, 2014). In this new economic context, olive cultivation seems to have played a less significant role compared to the preceding periods (with olive oil presumably imported, perhaps from the Levant: (Palmisano et al., in press)~~Palmisano et al., this issue)~~. Herding appears also not to have been pursued to the same degree as before, with regeneration of deciduous oak woods (and generally increased AP~~%~~) as a result and a much diminished imprint on the palynological record, although temporarily increased pastoral activity is evidenced in the Roman period (peak at ~1650 BP). The late Roman/early Byzantine phase, however, although known as an expansive period (Izdebski et al., 2015; Weiberg et al., 2016), is less visible in the cluster analysis and anthropogenic indicators of the present study compared with the subsequent economic and agropastoral expansion during middle Byzantine times ~~from~~ (Weiberg et al., 2016; Xoplaki et al., 2016).

Notably, the record from the north displays less of the boom and bust cycles present in the southern records, both in the pollen and the archaeological datasets, possibly reflecting the distance from the heartland of historical Greece in the south, but perhaps more likely a result~~s~~ of the high altitude locations of the large majority of the pollen cores. The change across time is instead overall more gradual. However, evidence for increased human pressure in the landscapes of the north from ~3000 BP does exist~~s nevertheless~~ and includes increasing values of *Cerealia*, *Juglans*, *Olea* (although much less distinct) and API, as well as all pastoral indicators **(Figure 7)**. The period (from ~3250 BP) also sees some increase in~~of~~ deciduous oak woods, possibly as a result of a closing of the deciduous oak parkland landscapes, but deciduous oak woods ~~are~~ declin~~eing~~ again along with AP~~%~~ after ~2000 BP. The site numbers for the north do not provide evidence of any major changes during this period (~~**Fig.**~~**Figure 4**). However, the fact that *Cerealia* continuously increases in the region from ~3000 BP (with a notable peak ~1800 BP, in the Roman period) would seem to suggest that the economic strategies were less specialized in the north compared to the south and that grain cultivation expanded over the whole region. Such cultivation could have been for local use but possibly also for export, in a region that due to bioclimatic conditions may have been more favourable for grain cultivation than the overall more arid south. Considering that *Olea* pollen are overall very rare in the north (~~Fig.~~**Figure** 7) and that no olive charcoal or olive stones have been recovered from prehistoric archaeological contexts in the north (Valamoti et al., 2018), the presence of *Olea* pollen in the prehistoric north should not be seen to indicate definite olive cultivation. The prevalence of olive stones from historical contexts in the north, however, suggest that more pollen cores from low altitude coastal locations may alter the visibility of olive pollen from the region for these later periods. According to Valamoti et al. (2018), cultivation of olives in the north was initiated in the littoral regions before 2500 BP and is attributable to the Greek colonization of these northern lands and the increasing needs of olive oil in the Archaic and Classical Greek societies.

Conclusions

This study demonstrates that the imprint of human activities on pollen records from Greece is more clearly visible in the later prehistoric and historic periods (from LH III onwards) in line with the emergence of more extensive agricultural strategies. This result also confirms arguments made by Mercuri et al. (in press)~~(this issue)~~ that Mediterranean land use before the LBA did not have a lasting effect on overall vegetation. In earlier periods, the location of pollen cores is an important factor, leading to opposite patterns in the south and north over the EN-LN time frame. More precisely, we probably see two sides of the same coin in these Neolithic phases due to the coastal location of the southern cores and the upland locations of the pollen cores in the north, signifying for both ~~areas~~ sub-regions a partial abandonment of coastal areas after the MN in favour of a more diversified use of the landscapes in the LN. More systematic and targeted core sampling in both regions could normalise these differences. During these early periods and into the Bronze Age, climate stands out as a potentially strong driver of vegetation changes over the long-term, ~~and also~~ amplifying the effect of changes caused by humans and possibly controlling regrowth, such as in the case of deciduous oak woods.

The radiocarbon SPD has also proven a useful tool for finding consistency and contrast in possible prehistoric population scenarios across the two sub-regions and ~~are broadly similar~~it is reassuring that the highs and lows of this time series in recognisingare consistently confirm traditionally identified cultural peak-and-trough--periods as those that also have a high demographic footprintin Aegean prehistory. They Radiocarbon densities also emphasise a likely increasing human presence in the LBA in a way that raw counts of archaeological site data do not, while furthermore nuancing narratives about the FN-EB I periods (especially in the south where surveys show a strong increase in site numbers that may only apply at the beginning and/or end of this long phase). That said, the amplitudes of the SPD should be treated cautiously and probably in relative rather than absolute terms given the overall sample size (e.g. without necessarily taking at face value equal amplitude of the earlier Neolithic and EBA inferred population levels, cf. (Timpson et al., 2014; cf. Roberts et al., in press)Timpson et al. 2014, 554). The consensus modelling attempted here builds on previous efforts (e.g. Palmisano et al., 2017) to suggest ways in which the strengths of different lines of evidence might be brought together. Multi-proxy analyses and inter-disciplinary communication are key to such integrative efforts and for the successful integration of the diverse and specialiszed archives available for the reconstruction of socio-ecological trajectories across time.

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Declaration of Conflicting Interests

The authors declare no conflict of interests.

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~~**Table**~~

~~Table 1. Approximate absolute chronology for the study and the associated relative cultural phases, with abbreviations used in the text (Arvaniti and Maniatis, 2018; Cavanagh et al., 2016; Maniatis, 2014; Manning, 2010; Weiberg et al., 2016). All dates given as BP are calibrated calendar years before present (where 'present' is defined as AD 1950). Dates in parentheses indicate evidence of human activity in some rare cases.~~

~~Table 2. Spearman's Rank Correlation Coefficient (R-values) value matrix for the period 10000–2800 cal BP for northern and southern Greece and both sub-regions combined. Statistical significance in bold values (p<0.05).~~

Figures

Figure 1. Distribution maps of (a) archaeological radiocarbon dates from Greece, and (b) major settlement surveys, pollen surface samples and fossil cores sites. Pollen: (1) Akovitika, (5–6) Asi Gonia, (7) Edessa, (8) Elefsis, (9) Aghia Galini, (10) Giannitsa B, (11) Lake Gramousti, (12) Halos I, (13–14) Ioannina, (15) Kastoria, (16–17) Khimaditis, (18) Kopais, (19) Lailias, (20) Lake Lerna, (21) Litochoro, (22-23) Nisi Fen, (24) Lake Orestiás, (25) Mount Paiko, (26) Pertouli, (27) Flambouro-Pieria mountains, (28) Rezina marsh, (29) Elatia-Rhodopes, (30) Tenaghi Philippon, (31) Trikhonis, (32) Tristinika, (33) Vegoritis, (34) Mount Voras, (35) Lake Voulkaria, (36) Vravron, (37) Lake Xinias. Surveys: (A) Asea Valley, (B) Berbati-Limnes, (C) Methana, (D) Southern Argolid, (E) Phlious Valley, (F) Pylos regions/Messenia, (G) Anthemountas, (H) Central Macedonia, (I,J) Sithonia, (K) Aliakmon, (L) Kitrini Limni, Kozani, (M) Langadas. For further information and references, see **~~SI~~ Supplementary Tables 2~~1~~-~~2~~3**.

Figure 2**.** Overall patterns in archaeological radiocarbon as (a) a summed probability distribution of calibrated dates that have been normalised in the traditional way, (b) the distribution when dates are left unnormalised (with basic archaeological periodisation overlaid), and (c) a test of the distribution in b against a fitted exponential model of population growth (grey critical envelope based on 1000 Monte Carlo simulations). In between (a) and (b) are 'barcodes' plotting the estimated median date for each radiocarbon sample as a further way to visualise the relative intensity of dates through time.

Figure 3. Regional radiocarbon trends for (a) northern Greece with both the focal region that most closely matches the pollen evidence and a wider region that maximises radiocarbon date sample size (both focal and other from figure 1), (b) southern Greece with the same split as a, and (c) a permutation test (1000 runs) of the departure of the northern region from what we might expect by chance.

Figure 4. Approaches to estimating site intensity from survey data from Macedonia: (a) raw count of 1 if a site's estimated date range covers a given year, (b) total surface area of sites whose estimated date ranges cover a given year, (c) aoristic sum of~~doe~~ sites that might fall in a given year (the three colour codes indicate how the calculations change if we take optimistic, moderate and pessimistic assumptions about the certainty of site identification and dating).

Figure 5. Approaches to estimating site intensity from survey data from the Peloponnese: (a) raw count of 1 if a site's estimated date range covers a given year, (b) total surface area of sites whose estimated date ranges cover a given year, (c) aoristic sum of ~~doe~~ sites that might fall in a given year (the three colour codes indicate how the calculations change if we take optimistic, moderate and pessimistic assumptions about the certainty of site identification and dating).

Figure 6. Cluster analyses of (a) northern Greece, and (b) southern Greece. Pollen-inferred vegetation cluster groups presented as percentage of pollen samples (time windows) assigned to each vegetation cluster group, and archaeological datasets (11000 BP~~—~~modern). The grey area highlights a period of low pollen site numbers. Regional palaeoclimate z-score mean for the Balkans region, based on sites from both north and south. Positive (negative) values indicate wetter (drier) conditions (for details see Finné et al., in press)~~(for details see Finné et al., this issue)~~. Horizontal bars show one standard deviation. The relative chronology is generalized to fit both sub-regions (for details see **Table 1**).

Figure 7. Pollen indicator groups for northern Greece (red curve) and southern Greece (blue curve) including arboreal pollen (~~%~~AP sum), human cultivars (*Cerealia*, OJC, *Juglans*, *Olea*), anthropogenic pollen index (API), summed grazing indicators (regional pastoral indicators, PDI and Cichori~~oid~~eae). The relative chronology is generalized to fit both sub-regions (for details see **Table 1**).

Figure 8. An example consensus model of the intensity of human activity, combining evidence from surveyed site areas and radiocarbon dates, based on data from prehistoric Peloponnese (cf. ~~**Fig.**~~**Figure 3** and ~~**Fig.**~~**Figure 5**).

Supplemental information

Supplementary Table 1. Metadata for radiocarbon dates from Greece used in the present study (see **Figure 1a** for geographical distribution).

Supplementary Table 2. Metadata for pollen assemblages from Greece used in the present study (the site numbers refer to the numbering in **Figure 1b,** giving the geographical locations of the pollen assemblages used).

Supplementary Table 3. Datasets used for the compilation of archaeological site data from the Peloponnese and Macedonia (**Figures 4-5**). Letters (A-N) refer to **Figure 1b** where the geographical location of the surveyed areas are indicated.

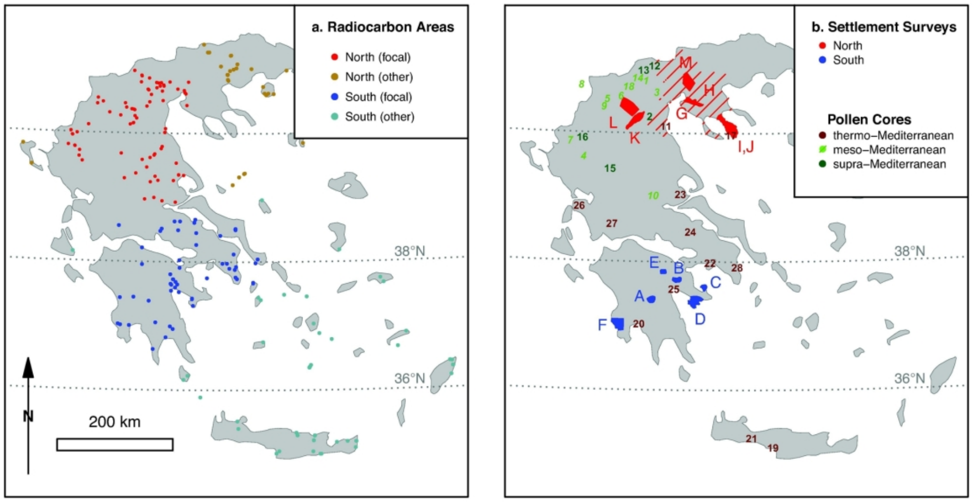

Figure 1. Distribution maps of (a) archaeological radiocarbon dates from Greece, and (b) major settlement surveys, pollen surface samples and fossil cores sites. Pollen: (1) Akovitika, (5–6) Asi Gonia, (7) Edessa, (8) Elefsis, (9) Aghia Galini, (10) Giannitsa B, (11) Lake Gramousti, (12) Halos I, (13–14) Ioannina, (15) Kastoria, (16–17) Khimaditis, (18) Kopais, (19) Lailias, (20) Lake Lerna, (21) Litochoro, (22-23) Nisi Fen, (24) Lake Orestiás, (25) Mount Paiko, (26) Pertouli, (27) Flambouro-Pieria mountains, (28) Rezina marsh, (29) Elatia-Rhodopes, (30) Tenaghi Philippon, (31) Trikhonis, (32) Tristinika, (33) Vegoritis, (34) Mount Voras, (35) Lake Voulkaria, (36) Vravron, (37) Lake Xinias. Surveys: (A) Asea Valley, (B) Berbati-Limnes, (C) Methana, (D) Southern Argolid, (E) Phlious Valley, (F) Pylos regions/Messenia, (G) Anthemountas, (H) Central Macedonia, (I,J) Sithonia, (K) Aliakmon, (L) Kitrini Limni, Kozani, (M) Langadas. For further information and references, see Supplementary Tables 2-3.

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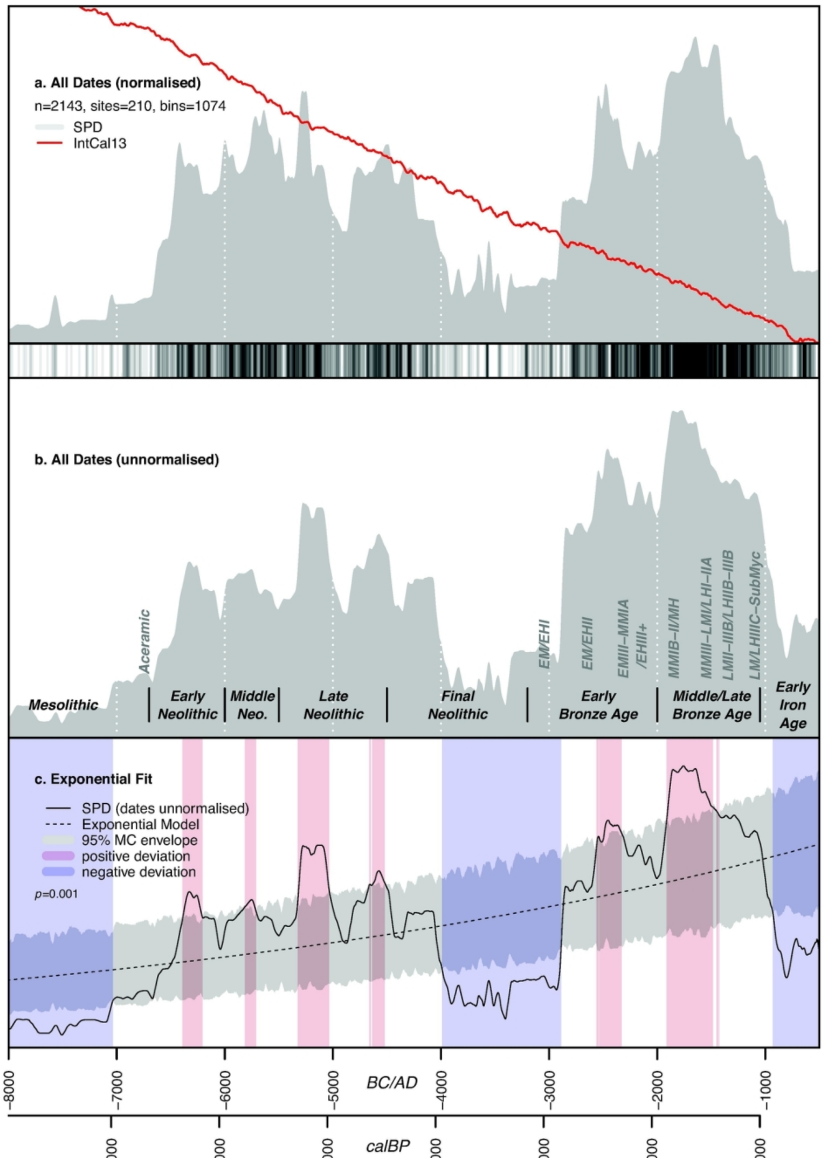

Figure 2. Overall patterns in archaeological radiocarbon as (a) a summed probability distribution of calibrated dates that have been normalised in the traditional way, (b) the distribution when dates are left unnormalised (with basic archaeological periodisation overlaid), and (c) a test of the distribution in b against a fitted exponential model of population growth (grey critical envelope based on 1000 Monte Carlo simulations). In between (a) and (b) are 'barcodes' plotting the estimated median date for each radiocarbon sample as a further way to visualise the relative intensity of dates through time.

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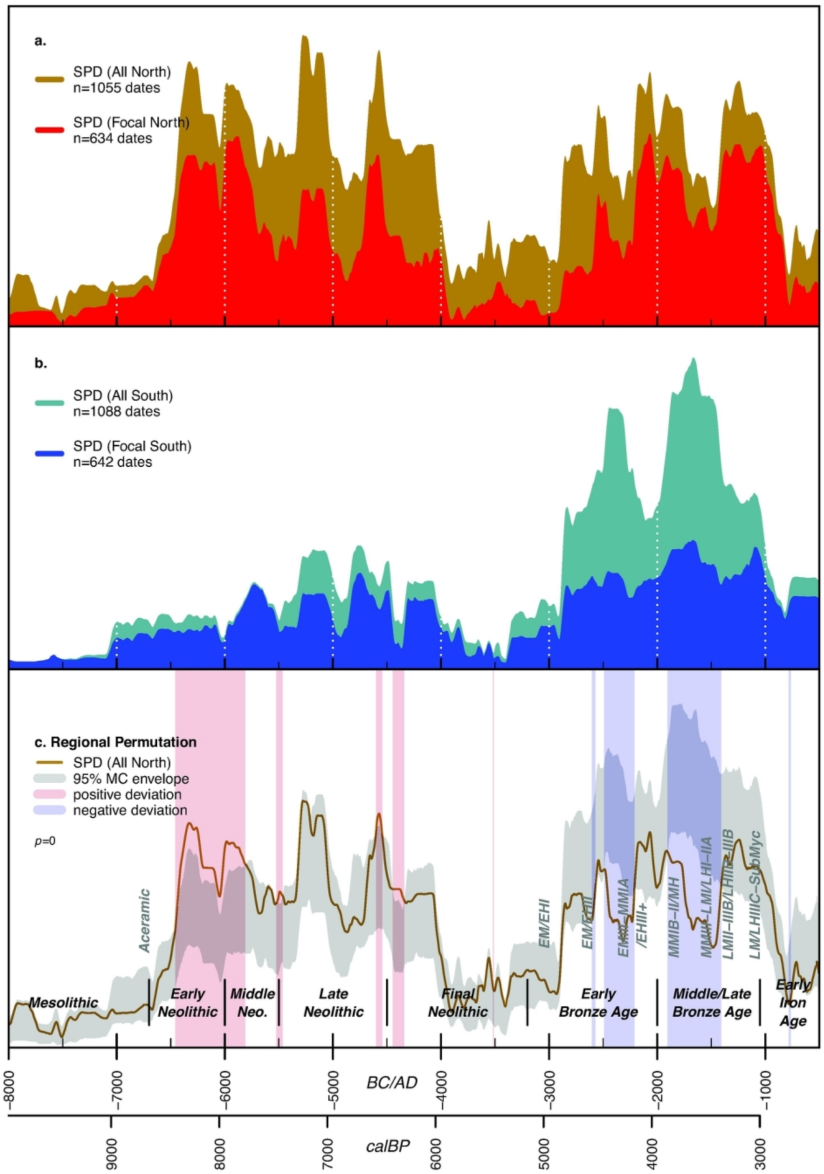

Figure 3. Regional radiocarbon trends for (a) northern Greece with both the focal region that most closely matches the pollen evidence and a wider region that maximises radiocarbon date sample size (both focal and other from figure 1), (b) southern Greece with the same split as a, and (c) a permutation test (1000 runs) of the departure of the northern region from what we might expect by chance.

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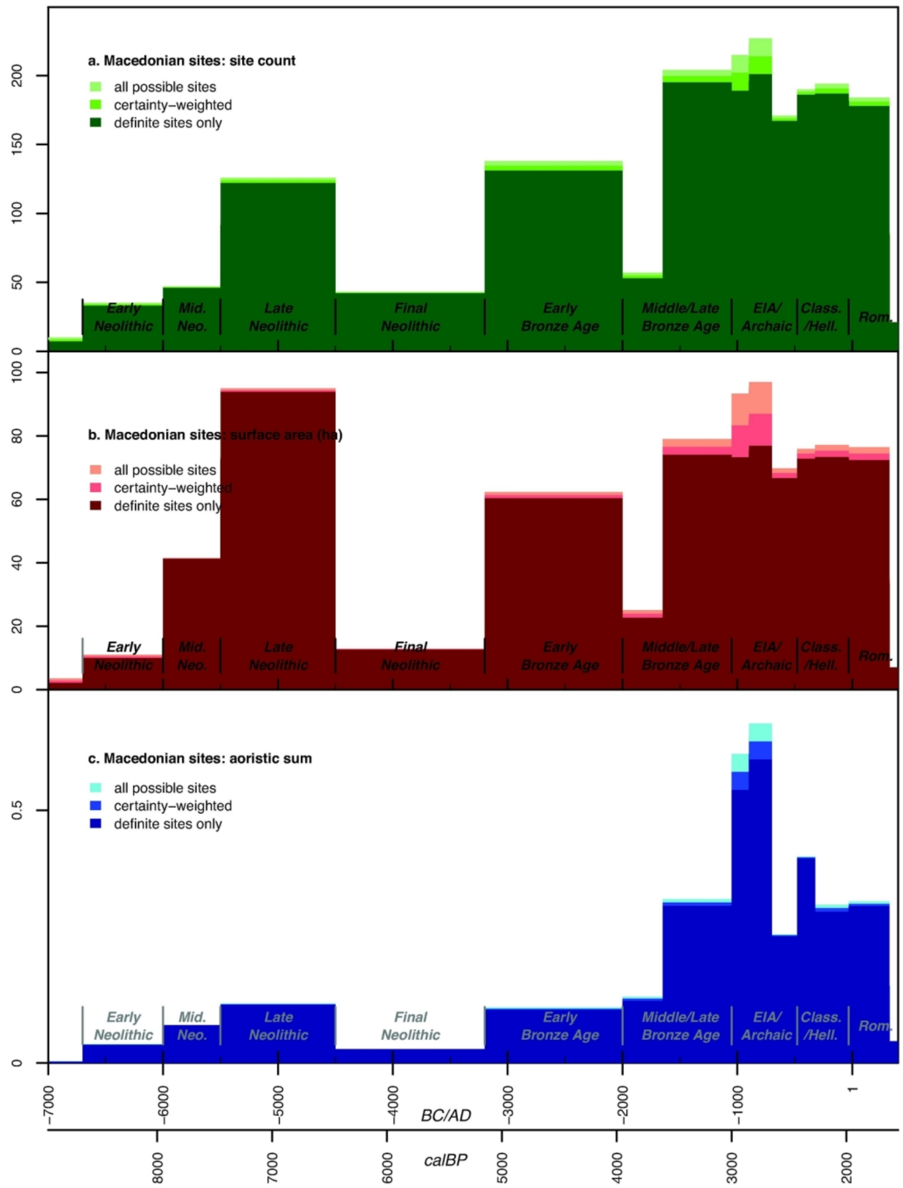

Figure 4. Approaches to estimating site intensity from survey data from Macedonia: (a) raw count of 1 if a site's estimated date range covers a given year, (b) total surface area of sites whose estimated date ranges cover a given year, (c) aoristic sum of sites that might fall in a given year (the three colour codes indicate how the calculations change if we take optimistic, moderate and pessimistic assumptions about the certainty of site identification and dating).

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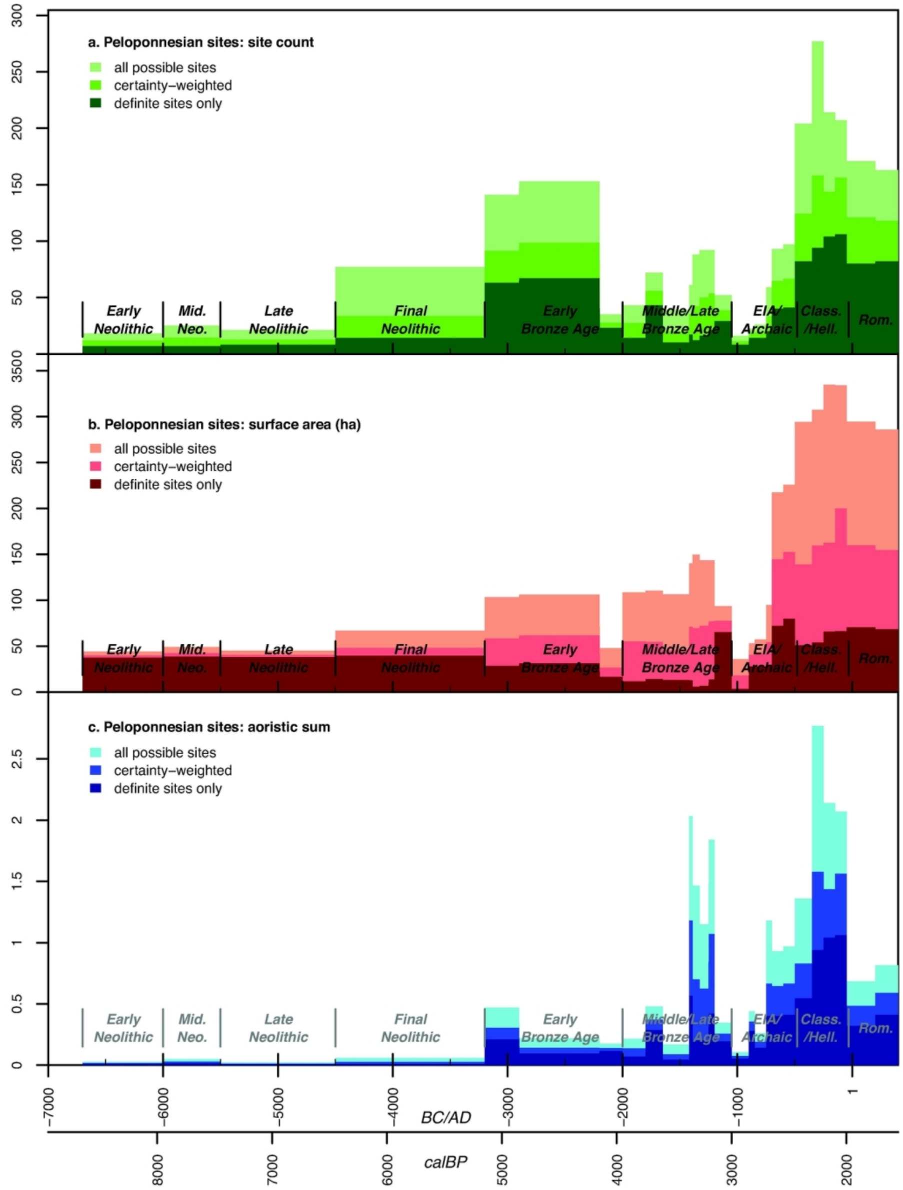

Figure 5. Approaches to estimating site intensity from survey data from the Peloponnese: (a) raw count of 1 if a site's estimated date range covers a given year, (b) total surface area of sites whose estimated date ranges cover a given year, (c) aoristic sum of sites that might fall in a given year (the three colour codes indicate how the calculations change if we take optimistic, moderate and pessimistic assumptions about the certainty of site identification and dating).

139x180mm (300 x 300 DPI)

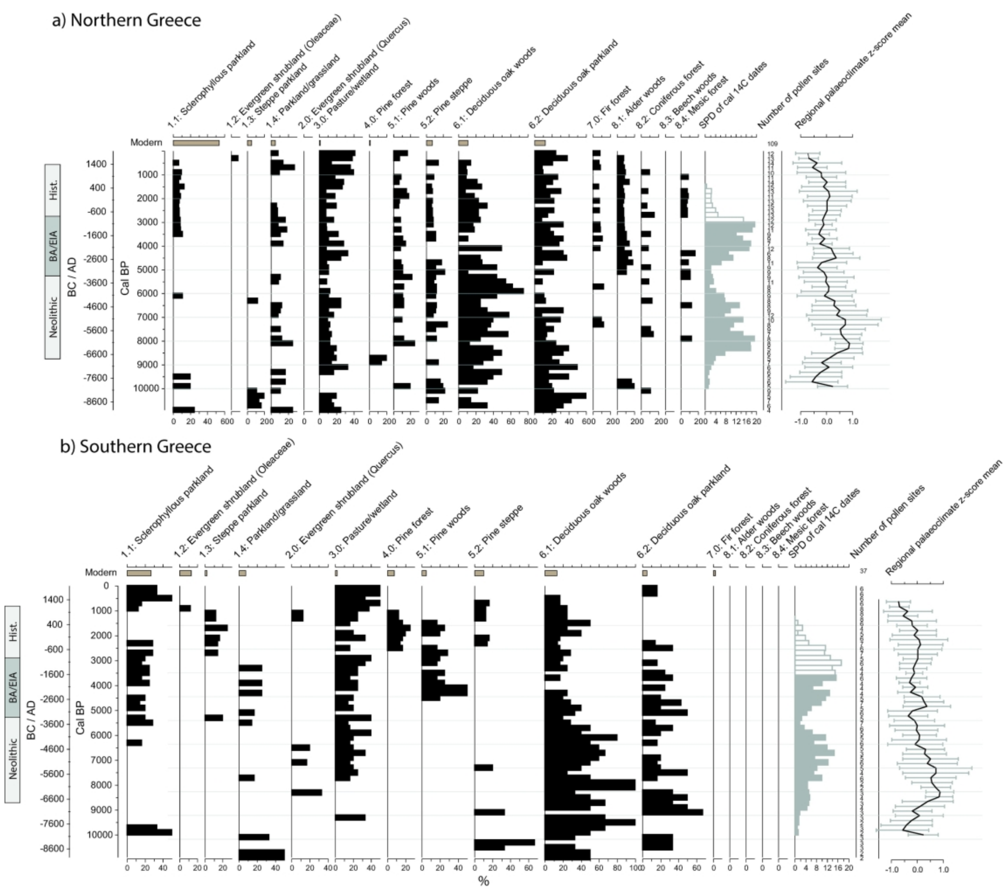

Figure 6. Cluster analyses of (a) northern Greece, and (b) southern Greece. Pollen-inferred vegetation cluster groups presented as percentage of pollen samples (time windows) assigned to each vegetation cluster group, and archaeological datasets (11000 BP–modern). The grey area highlights a period of low pollen site numbers. Regional palaeoclimate z-score mean for the Balkans region, based on sites from both north and south. Positive (negative) values indicate wetter (drier) conditions (for details see Finné et al., in press). Horizontal bars show one standard deviation. The relative chronology is generalized to fit both sub-regions (for details see Table 1).

224x197mm (300 x 300 DPI)

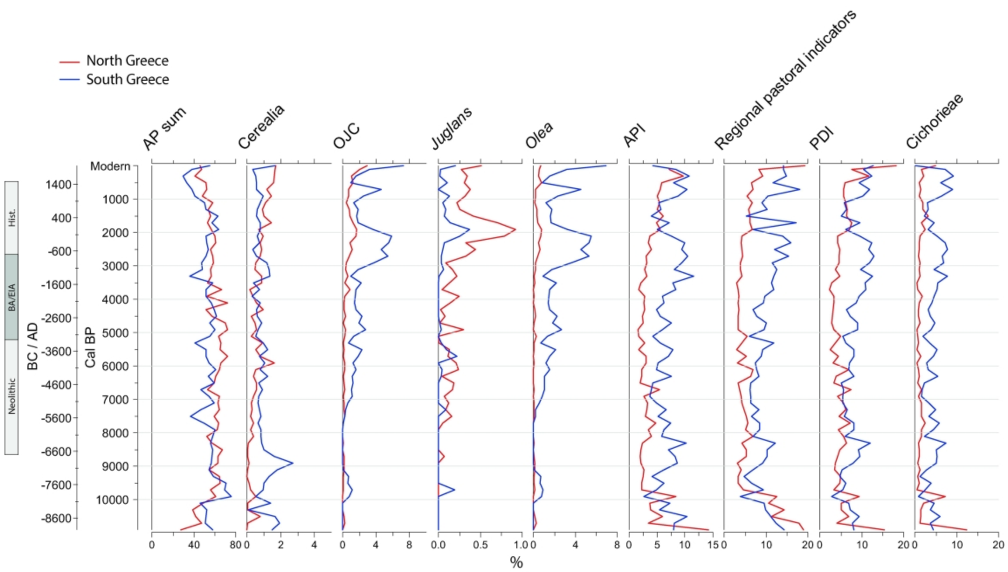

Figure 7. Pollen indicator groups for northern Greece (red curve) and southern Greece (blue curve) including arboreal pollen (AP sum), human cultivars (Cerealia, OJC, Juglans, Olea), anthropogenic pollen index (API), summed grazing indicators (regional pastoral indicators, PDI and Cichorieae). The relative chronology is generalized to fit both sub-regions (for details see Table 1).

254x144mm (300 x 300 DPI)

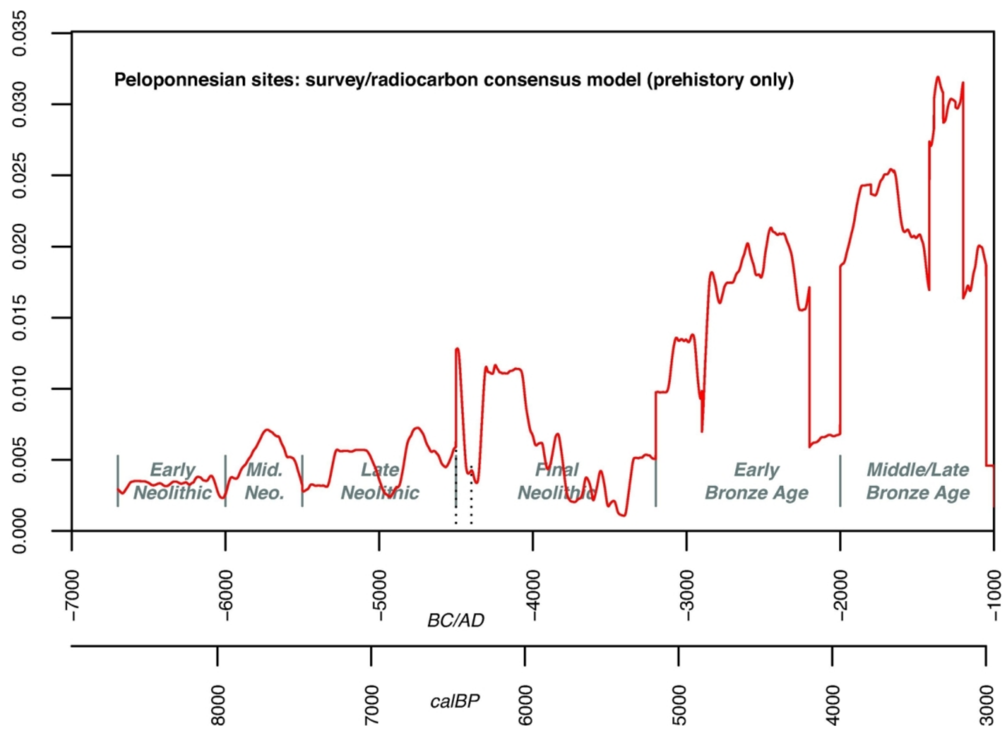

Figure 8. An example consensus model of the intensity of human activity, combining evidence from surveyed site areas and radiocarbon dates, based on data from prehistoric Peloponnese (cf. Figure 3 and Figure 5).

132x94mm (300 x 300 DPI)

SUPPLEMENTAL MATERIAL

Long-term trends of land use and demography in Greece: a comparative study

Weiberg, E., A. Bevan, K. Kouli, M. Katsianis, J. Woodbridge, A. Bonnier, M. Engel, M. Finné, R. Fyfe, Y. Maniatis, A. Palmisano, N. Roberts, S. Shennan

Supplementary Table 1. Metadata for radiocarbon dates from Greece used in the present study (see **Figure 1a** for geographical distribution).

SiteName	nDates	AdminRegion	StudyRegion	References
Kokkika Vrachia, Fea Petra	1	Central Macedonia	North	Maniatis 2014
Kryoneri, Nea Kerdyllia	8	Central Macedonia	North	Malamidou 2016; Maniatis et al.. 2014; Maniatis et al.. 2016
Pentapolis	6	Central Macedonia	North	Fossey 1987; Grammenos 1983; Manning 1995
Promachonas-Topolnitsa	14	Central Macedonia	North	Boyadzhiev 1995; Boyadzhiev 1992; Görsdorf and Boyadzhiev 1996; Koukouli-Chryssanthaki et al. 2003; Koukouli-Chryssanthaki et al. 2007; Manning et al. 2015 (EUROEVOL db); Reingruber and Thissen 2016 (14SEA db); Weninger 2017 (CalPal db)
Sidirokastro-Katarraktes	20	Central Macedonia	North	Arvaniti and Maniatis 2018; Maniatis 2014; Maniatis et al. 2014; Maniatis et al. 2016
Stathmos Aggistas, Serres	1	Central Macedonia	North	Evin et al. 1983
Aghios Antonios Potos, Thassos	9	Eastern Macedonia and Thrace	North	Arvaniti and Maniatis 2018; Maniatis et al. 2015; Maniatis et al. 2016
Aghios Ioannis, Thassos	8	Eastern Macedonia and Thrace	North	Arvaniti and Maniatis 2018; Maniatis and Papadopoulos 2011; Maniatis et al. 2014
Amphipolis bridge	13	Eastern Macedonia and Thrace	North	Maniatis et al. 2010
Dikili Tash	114	Eastern Macedonia and Thrace	North	Ammerman et al. 2008; Arvaniti and Maniatis 2018; Brami and Zanotti 2015; CDRC 2016 (Banadora db); Evin et al. 1979; Facorellis 1996; Hinz et al. 2012 (RADON db); Lespez et al. 2013; Maniatis et al. 2014; Maniatis et al. 2016; Manning 1995; Manning et al. 2015 (EUROEVOL db); Seferiades 1983; Treuil 1983; Treuil 1992; Weninger 2017 (CalPal db)
Dimitra	1	Eastern Macedonia and Thrace	North	Maniatis 2014; Maniatis et al. 2011
Fidokoryphi	12	Eastern Macedonia and Thrace	North	Lespez et al. 2016
Kastri Theologos, Thassos	8	Eastern Macedonia and Thrace	North	Maniatis et al. 2016

Krovili	5	Eastern Macedonia and Thrace	North	Ammerman et al. 2008; Manning et al. 2015 (EUROEVOL db); Weninger 2017 (CalPal db)
Lafrouda	6	Eastern Macedonia and Thrace	North	Ammerman et al. 2008; Manning et al. 2015 (EUROEVOL db); Weninger 2017 (CalPal db)
Limenaria, Thasos	22	Eastern Macedonia and Thrace	North	Maniatis and Fakorellis 2012; Papadopoulos and Malamidou 2008
Maara cave, Drama	7	Eastern Macedonia and Thrace	North	Facorellis 2013; Trantalidou et al. 2005; Weninger 2017 (CalPal db)
Makri, Evros	17	Eastern Macedonia and Thrace	North	Ammerman et al. 2008; Brami and Zanotti 2015; Efstratiou et al. 1998; Hinz et al. 2012 (RADON db); Karkanas and Efstratiou 2009
Mikro Vouni, Samothrace	54	Eastern Macedonia and Thrace	North	Facorellis 1996; Maniatis 2014; Matsas 1995
Orfeas cave, Alistrati	3	Eastern Macedonia and Thrace	North	Maniatis 2014; Maniatis et al. 2011
Sitagroi	29	Eastern Macedonia and Thrace	North	Arvaniti and Maniatis 2018; Brami and Zanotti 2015; Breunig 1987; Burleigh et al. 1977; Durman and Obelic 1989; Ehrich and Bankoff 1992; Hinz et al. 2012 (RADON db); Johnson 1999; Manning 1995; Manning et al. 2015 (EUROEVOL db); Renfrew 1971; Renfrew et al. 1986; Weninger 2017 (CalPal db)
Skala Sotiros	16	Eastern Macedonia and Thrace	North	Arvaniti and Maniatis 2018
Toumba Kokkinochoma, Proskinites	2	Eastern Macedonia and Thrace	North	Pinhasi et al. 2005
Grava, Corfu	1	Ionian Islands	North	Facorellis 2003; Facorellis 2013; Gowlett et al. 1997; Hinz et al. 2012 (RADON db)
Sidari, Corfou	17	Ionian Islands	North	Berger et al. 2014; CDRC 2016 (Banadora db); Facorellis 2003; Hinz et al. 2012 (RADON db); Manning et al. 2015 (EUROEVOL db); Perlès 2001; Sordinas 1967; Sordinas 1969; Sordinas 2003; Weninger 2017 (CalPal db)
Poliochni, Limnos	1	North Aegean	North	Demokritos (Maniatis pers.comm.)
Aghios Petros, Kyra Panagia	1	Thessaly	North	Bowman et al. 1990; Brami and Zanotti 2015; Efstratiou 1985; Reingruber and Thissen 2005
Alonissos shipwreck	1	Thessaly	North	Facorellis 1996
Cyclops Cave, Youra	21	Thessaly	North	Brami and Zanotti 2015; Facorellis 1996; Facorellis 2003; Facorellis 2011; Facorellis 2013; Facorellis and Vardala-Theodorou 2015; Facorellis et al. 1998; Manning et al. 2015 (EUROEVOL db); Reingruber and Thissen 2005; Sampson 1998; Sampson et al. 1999; Trantalidou 2014; Weninger 2017 (CalPal db)
Gioura	3	Thessaly	North	Girdland-Flink 2013
Archanes, Othrys Mountains	1	Central Greece	North Core	Hedges et al. 1993b; ORAU 2016 (ORAU db); Weninger 2017 (CalPal db)

Imvrou Pigadi	2	Central Greece	North Core	Kyparissi-Apostolika pers.comm.; Reingruber and Thissen 2016 (14SEA db)
Kalamakia, Othrys Mountains	2	Central Greece	North Core	Hedges et al. 1993b; ORAU 2016 (ORAU db)
Limogardi, Othrys Mountains	1	Central Greece	North Core	Hedges et al. 1993b; Hinz et al. 2012 (RADON db)
Palaeo-Spartia, Othrys Mountains	1	Central Greece	North Core	Hedges et al. 1993b; ORAU 2016 (ORAU db)
Agiasma cave A, Loutraki Aridaia	4	Central Macedonia	North Core	Demokritos (Maniatis pers.comm.); Kambouroglou et al. 2007; Kambouroglou et al. 2008
Archontiko, Yannitsa	40	Central Macedonia	North Core	Arvaniti and Maniatis 2018; Demokritos (Maniatis pers.comm.); Facorellis 1996; Maniatis 2013; Papadopoulou et al. 2010; Papaefthimiou-Papanthimou and Pilali-Papasteriou 1996; Papaefthimiou-Papanthimou and Pilali-Papasteriou 1998; Pilali-Papasteriou and Papaefthimiou-Papanthimou 1995; Pilali-Papasteriou et al. 2001
Asomata, Veroia	1	Central Macedonia	North Core	Koukouvou 2003
Assiros	67	Central Macedonia	North Core	Burleigh et al. 1982a; Manning and Weninger 1992; Newton et al. 2005; ORAU 2016 (ORAU db); Wardle et al. 2014
Axos, Pella	1	Central Macedonia	North Core	Maniatis et al. 2011
Edessa	1	Central Macedonia	North Core	Chrysostomou 2010
Giannitsa B	2	Central Macedonia	North Core	Maniatis 2014; Maniatis et al. 2011
Kanali, Pella	2	Central Macedonia	North Core	Maniatis 2014
Kastanas	54	Central Macedonia	North Core	Manning and Weninger 1992; Weninger 2017 (CalPal db)
Lefkopetra	2	Central Macedonia	North Core	Maniatis 2014; Maniatis et al. 2011
Mandalo, Pella	20	Central Macedonia	North Core	Maniatis and Kromer 1990; Manning 1995; Manning et al. 2015 (EUROEVOL db); Weninger 2017 (CalPal db)
Mesimeriani Toumba, Trilofos	10	Central Macedonia	North Core	Arvaniti and Maniatis 2018; Maniatis 2013; Maniatis 2002
Nea Nikomedeia	15	Central Macedonia	North Core	Brami and Zanotti 2015; Facorellis 2003; Godwin and Willis 1962; Hinz et al. 2012 (RADON db); Maniatis 2014; Maniatis et al. 2011; Manning et al. 2015 (EUROEVOL db); Perlès 2001; Pyke and Yiouni 1996; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Rodden et al. 1996; Stuckenrath 1967; Weninger 2017 (CalPal db)
Paliambela, Pieria	11	Central Macedonia	North Core	Maniatis 2014; Maniatis et al. 2011
Pigi Athinas, Platamon	1	Central Macedonia	North Core	Maniatis 2014
Polyplatanos, Veroia	4	Central Macedonia	North Core	Demokritos (Maniatis pers.comm.); Merousis 2004
Rotunda of Galerius, Thessaloniki	1	Central Macedonia	North Core	Korozi et al. 2001

Sindos Block-55	1	Central Macedonia	North Core	Antikas and Antika 2006
Skotina, Pieria	6	Central Macedonia	North Core	Demokritos (Maniatis pers.comm.); Maniatis 2014
Stavroupoli, Thessaloniki	6	Central Macedonia	North Core	Maniatis et al. 2002
Thessaloniki Plain	4	Central Macedonia	North Core	Ghilardi 2010
Thessaloniki Toumba	20	Central Macedonia	North Core	Andreou 2009; Newton et al. 2005; Thessaloniki Toumba Excavation
Valtos, Leptokarya	2	Central Macedonia	North Core	Poulaki-Pantermali et al. 2010
Asfaca, Ioannina	2	Epirus	North Core	Adam et al. 2011
Asfaka	1	Epirus	North Core	Higgs and Vita-Finzi 1966; Hinz et al. 2012 (RADON db); Perlès 2001; Weninger 2017 (CalPal db)
Klithi	1	Epirus	North Core	Bailey and Galanidou 2009; Facorellis 2013; Gowlett et al. 1986; Hinz et al. 2012 (RADON db)
Krya I	1	Epirus	North Core	Vasileiou 2016
Krya II	1	Epirus	North Core	Vasileiou 2016
Liatovouni I	1	Epirus	North Core	Vasileiou 2016
Mazaraki, Doliana	1	Epirus	North Core	Hedges et al. 1990; Hinz et al. 2012 (RADON db)
Megalakkos	1	Epirus	North Core	Facorellis 2003; Facorellis 2013; Gowlett et al. 1997; Hedges et al. 1990; Hinz et al. 2012 (RADON db)
Palabouti	1	Epirus	North Core	Vasileiou 2016
Rezina Marsh	1	Epirus	North Core	Hedges et al. 1990; Hinz et al. 2012 (RADON db); Willis 1992
Serviana	2	Epirus	North Core	Maniatis et al. 2016
Achilleion	43	Thessaly	North Core	Brami and Zanotti 2015; Gimbutas 1974; Gimbutas et al. 1989; Hinz et al. 2012 (RADON db); Lawn 1975; Linick 1977; Linick 1980; Manning et al. 2015 (EUROEVOL db); Perlès 2001; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Weninger 2017 (CalPal db); Weninger et al. 2014
Amygdalies, Mikrothives	6	Thessaly	North Core	Maniatis et al. 2016
Argissa Magoula	13	Thessaly	North Core	Arvaniti and Maniatis 2018; Brami and Zanotti 2015; Coleman 1992; Demoule and Perles 1993; Facorellis 2003; Gimbutas et al. 1989; Hinz et al. 2012 (RADON db); Manning 1995; Manning et al. 2015 (EUROEVOL db); Milojcic 1973; Perlès 2001; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Vogel and Waterbolk 1967; Weninger 2017 (CalPal db)
Argissa Magoula; Dhimini	1	Thessaly	North Core	Renfrew 1971
Makrychori, Larissa	3	Thessaly	North Core	Maniatis et al. 2016
Mandra, Koilada	3	Thessaly	North Core	Maniatis et al. 2016
Otzaki Magoula	2	Thessaly	North Core	Brami and Zanotti 2015; Reingruber and Thissen 2005
Palioskala Agias	6	Thessaly	North Core	Maniatis et al. 2016
Pevkakia	10	Thessaly	North Core	Johnson 1999; Manning 1995; Weisshaar 1989; Weninger 2017 (CalPal db)

Plastiras Lake	4	Thessaly	North Core	Krauß et al. 2016; Kyparissi-Apostolika pers.comm.; Reingruber and Thissen 2016 (14SEA db)
Platia Magoula Zarkou	6	Thessaly	North Core	Brami and Zanotti 2015; Facorellis 1996; Reingruber and Thissen 2005
Prodromos III (Magoula Agios Ioannis), Karditsa	9	Thessaly	North Core	Maniatis et al. 2016
Rachmani	3	Thessaly	North Core	Maniatis et al. 2016
Sesklo A	11	Thessaly	North Core	Brami and Zanotti 2015; Hinz et al. 2012 (RADON db); Lawn 1973; Perlès 2001; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Weninger 2017 (CalPal db)
Sesklo B	3	Thessaly	North Core	Brami and Zanotti 2015; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Weninger 2017 (CalPal db)
Sesklo C	1	Thessaly	North Core	Brami and Zanotti 2015; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Weninger 2017 (CalPal db)
Sykeon	4	Thessaly	North Core	Maniatis et al. 2016
Theopetra Cave, Kalambaka	40	Thessaly	North Core	Brami and Zanotti 2015; Facorellis 1996; Facorellis 2003; Facorellis 2013; Facorellis et al. 2001; Karkanas 2001; Kyparissi-Apostolika 1999; Manning et al. 2015 (EUROEVOL db); Ntinou and Kyparissi-Apostolika 2016; Perlès 2001; Reingruber and Thissen 2005; Weninger 2017 (CalPal db)
Vassilis, Farsala	3	Thessaly	North Core	Maniatis et al. 2016; Toufexis et al. 2012
Aggelochori, Imathia	13	Western Macedonia	North Core	Maniatis 2010
Avgi	12	Western Macedonia	North Core	Kalogiropoulou 2013
Dispilio, Kastoria	34	Western Macedonia	North Core	Facorellis 1996; Facorellis et al. 2014; Karkanas et al. 2011; Maniatis et al. 2016; Pinhasi et al. 2005
Fyllotsairi, Mavropigi	23	Western Macedonia	North Core	Brami and Zanotti 2015; Karamitrou-Mentesidi 2014; Karamitrou-Mentessidi et al. 2013; Maniatis 2014; Maniatis et al. 2011; Weninger et al. 2014
Grammi, Apsalos Aridaia	4	Western Macedonia	North Core	Chrysostomou et al. 2003; Demokritos (Maniatis pers.comm.)
Kitrini Limni	1	Western Macedonia	North Core	NA
Komvos Apsalos, Aridaia	2	Western Macedonia	North Core	Chrysostomou and Georgiadou 2003
Kryopigado, Neapoli	12	Western Macedonia	North Core	Demokritos (Maniatis pers.comm.); Maniatis 2014
Megali Toumba Agiou Dimitriou, Kitrini Limni	4	Western Macedonia	North Core	Fotiadis and Chondrogianni-Metoki 1997
Paliambela Roditis, Aliakmon	1	Western Macedonia	North Core	Maniatis 2014
Piges Koromilias, Kastoria	3	Western Macedonia	North Core	Facorellis 2013; Trantalidou et al. 2010
Polemistra, Aiani	1	Western Macedonia	North Core	Chondrogianni-Metoki 1998
Porta, Ksirolimni Kozani	3	Western Macedonia	North Core	Karamitrou-Mentesidi 2014
Samarina 8, Grevena	3	Western Macedonia	North Core	Efstratiou et al. 2006

Servia-Varytimidhes	11	Western Macedonia	North Core	Bowman et al. 1990; Brami and Zanotti 2015; Burleigh and Hewson 1979; Burleigh et al. 1982b; Manning et al. 2015 (EUROEVOL db); Perlès 2001; Reingruber and Thissen 2005; Weninger 2017 (CalPal db)
Toumba Kremastis Koiladas	19	Western Macedonia	North Core	Maniatis 2013
Tourla, Goules	2	Western Macedonia	North Core	Ziota 2007
Varemenoi-Goulon	2	Western Macedonia	North Core	Chondrogianni-Metoki 2002; Chondrogianni-Metoki 2009; Maniatis 2014; Maniatis et al. 2011
Vrysi, Pontokomi	1	Western Macedonia	North Core	Karamitrou-Mentesidi 2014
Xeropigado Koiladas	17	Western Macedonia	North Core	Maniatis and Ziota 2011; Weninger 2017 (CalPal db); Ziota 2007
Antikythera shipwreck	1	Attica	South	Stuckenrath et al. 1966
Livadi section, Kythera	1	Attica	South	Krahtopoulou and Frederick 2008
Paleopolis roadcut, Kythera	1	Attica	South	Krahtopoulou and Frederick 2008
Palamari, Skyros	17	Central Greece	South	Arvaniti and Maniatis 2018; Facorellis and Vardala-Theodorou 2015; Maniatis and Arvaniti 2015
Candia	1	Crete	South	Bronk Ramsey et al. 2002; Hinz et al. 2012 (RADON db)
Chania	8	Crete	South	Bronk Ramsey et al. 2004; Höflmayer 2010; Housley et al. 1999; Manning 2009; Manning and Bronk Ramsey 2009; Manning et al. 2002; Manning et al. 2006
Karphi	5	Crete	South	Wallace and Mylona 2012
Knossos	69	Crete	South	Barker and Mackey 1963; Barker et al. 1969; Betancourt et al. 1978; Brami and Zanotti 2015; Burleigh and Matthews 1982; Burleigh et al. 1977; Demoule and Perles 1993; Efstratiou 2014; Evans 1968; Facorellis 2003; Facorellis and Maniatis 2013; Fishman and Law 1978; Hinz et al. 2012 (RADON db); Höflmayer 2010; Kutschera and Stadler 2000; MacDonald and Knappett 2007; Manning and Weninger 1992; Manning et al. 2015 (EUROEVOL db); Momigliano and Wilson 1996; Myers et al. 1992; Perlès 2001; Reingruber 2015; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Renfrew 1971; Stuckenrath and Lawn 1969; Tomkins 2007; Warren 1976; Warren et al. 1968; Weinstein and Michael 1978; Weninger 2017 (CalPal db); Zouridakis et al. 1987
Knossos, Unexplored Mansion	10	Crete	South	Bronk Ramsey et al. 2004; Fishman and Law 1978; Hedges et al. 1990; Höflmayer 2010; Kutschera and Stadler 2000; Manning 2009; Manning and Bronk Ramsey 2009; Manning and Weninger 1992; Manning et al. 2006; Myers et al. 1992
Kommos	24	Crete	South	Bronk Ramsey et al. 2004; Höflmayer 2010; Manning and Bronk Ramsay 2009; Manning et al. 2006
Malia	11	Crete	South	Myers et al. 1992; Weinstein and Michael 1978

Mochlos	5	Crete	South	Höflmayer 2010; Manning 2009; Manning and Bronk Ramsey 2009; Soles 2004
Myrtos-Phournou Korifi	7	Crete	South	Manning 1995; Manning et al. 2015 (EUROEVOL db); Momigliano and Wilson 1996; Myers et al. 1992; Renfrew 1971; Switsur and West 1972; Switsur et al. 1970; Warren 1976; Weninger 2017 (CalPal db)
Myrtos-Pyrgos	19	Crete	South	Betancourt et al. 1978; Bronk Ramsey et al. 2004; Fishman and Law 1978; Höflmayer 2010; Housley et al. 1999; Manning 1988; Manning 2009; Manning and Bronk Ramsey 2009; Manning et al. 2002; Manning et al. 2006; Myers et al. 1992
Palaikastro	8	Crete	South	Betancourt et al. 1978; Bruins and van der Plicht 2014; Bruins et al. 2008; Bruins et al. 2009; Engstrand 1965; Höflmayer 2010; Manning 1988; Myers et al. 1992
Petras	1	Crete	South	Van Strydonck and De Roock 2017 (Kikirpa db)
Phaistos	3	Crete	South	Hinz et al. 2012 (RADON db); Levi 1960; Myers et al. 1992; Renfrew 1968
Plagiada	1	Crete	South	Manning 1988; Meulengracht et al. 1981
Platyvola Cave	4	Crete	South	Bowman et al. 1990; Burleigh et al. 1982b; Facorellis 2013
Zakros, Crete	1	Crete	South	Lawn 1975; Manning 1988; Myers et al. 1992
Drakaina Cave, Kephalonia	12	Ionian Islands	South	Facorellis 1996; Facorellis 2013; Pinhasi et al. 2005; Stratouli et al. 1998
Emporio, Chios	1	North Aegean	South	Manning et al. 2015 (EUROEVOL db); Ralph and Stuckenrath 1962; Weninger 2017 (CalPal db)
Aghios Georgios Cave, Kalithies, Rhodes	2	South Aegean	South	Facorellis 2013; Sampson et al. 1999
Akrotiri, Thera	119	South Aegean	South	Aitken 1988; Arvaniti and Maniatis 2018; Bronk Ramsey et al. 2004; Bruins and van der Plicht 2014; Fishman and Law 1978; Fishman et al. 1977; Friedrich et al. 2006; Hedges et al. 1990; Heinemeier et al. 2009; Hinz et al. 2012 (RADON db); Höflmayer 2010; Hurst and Lawn 1984; Kutschera and Stadler 2000; Maniatis 2012; Manning 1988; Manning 2008; Manning and Bronk Ramsay 2009; Manning and Bronk Ramsey 2009; Manning et al. 2002; Manning et al. 2006; Manning et al. 2014; Meulengracht et al. 1981; ORAU 2016 (ORAU db); Panagiotakopulu et al. 2013; Panagiotakopulu et al. 2015; Weinstein and Michael 1978
Akrotiri, Thera (Boudouroglou Mine)	1	South Aegean	South	Aitken 1988; Fishman et al. 1977; Kutschera and Stadler 2000; Manning 1988; Weinstein and Michael 1978
Asomatos Kremastis, Rhodes	1	South Aegean	South	Marketou et al. 2001
Athinios Quarry, Thera	1	South Aegean	South	Kutschera and Stadler 2000; Manning 1988
Dhaskalio Kavos, Keros	3	South Aegean	South	Hedges et al. 1992; Hinz et al. 2012 (RADON db); Manning 2008; Marangou et al. 2006; Weninger 2017 (CalPal db)

Dhaskalio, Keros (special deposit south)	16	South Aegean	South	Arvaniti and Maniatis 2018; Bronk Ramsey et al. 2013; Hinz et al. 2012 (RADON db); ORAU 2016 (ORAU db); Renfrew 2013; Renfrew et al. 2012; Weninger 2017 (CalPal db)
Ermis mine, Thera	2	South Aegean	South	Facorellis 1996
Ftelia, Mykonos	9	South Aegean	South	Facorellis and Maniatis 2002; Facorellis and Vardala-Theodorou 2015
Giali, Nisiros	1	South Aegean	South	Facorellis 1996
Heraion, Samos	6	South Aegean	South	Niemeier and Maniatis 2010
Kalithies, Rhodes	1	South Aegean	South	Facorellis 1996
Kastri, Syros	1	South Aegean	South	Megaw 1968
Koumelo Cave, Archangelos, Rhodes	2	South Aegean	South	Facorellis 2013; Sampson et al. 1999
Markiani, Amorgos	12	South Aegean	South	Arvaniti and Maniatis 2018; Hinz et al. 2012 (RADON db); Maniatis and Arvaniti 2015; Manning 2008; Marangou et al. 2006
Maroulas, Kythnos	9	South Aegean	South	Brami and Zanotti 2015; Facorellis et al. 2010; Manning et al. 2015 (EUROEVOL db); Reingruber and Thissen 2005; Weninger 2017 (CalPal db)
Naxos	2	South Aegean	South	Facorellis 1996
Phira Quarries, Thera	2	South Aegean	South	Fishman et al. 1977; Kutschera and Stadler 2000; Manning 1988; Olson and Broecker 1959; Weinstein and Michael 1978
Samos, Kouros figure	1	South Aegean	South	Burleigh and Hewson 1979
Serayia, Kos	2	South Aegean	South	Marketou et al. 2001
Skouries, Kythnos	2	South Aegean	South	Hedges et al. 1990; Hinz et al. 2012 (RADON db)
Thera, ravine east of Akrotiri	1	South Aegean	South	Zouridakis et al. 1987
Trianda, Rhodes	31	South Aegean	South	Bronk Ramsey et al. 2004; Facorellis 1996; Höflmayer 2010; Manning and Bronk Ramsey 2009; Manning et al. 2002; Manning et al. 2006; Marketou et al. 2001
Upper Phylakopi Valley, Melos	1	South Aegean	South	Harkness 1981
Zas cave, Naxos	8	South Aegean	South	Arvaniti and Maniatis 2018; Facorellis 2013; Manning 2008
Agora, Athens	1	Attica	South Core	Fishman et al. 1977; Shear 1973
Ari, Lavrion	2	Attica	South Core	Tsaimou et al. 2015
Kitsos Cave, Lavrion	13	Attica	South Core	Brami and Zanotti 2015; Delibrias et al. 1974; Facorellis 2013; Hinz et al. 2012 (RADON db); Johnson 1999; Sampson et al. 1999; Weninger et al. 2014
Kolonna, Aegina	56	Attica	South Core	Arvaniti and Maniatis 2018; Felber 1975; Höflmayer 2010; Maniatis and Arvaniti 2015; Manning 1995; Walter and Felten 1981; Wild et al. 2010

Lake Vouliagmeni, Perakhora	10	Attica	South Core	Fishman and Law 1978; Fossey 1987; Linick 1979; Manning 1995; Sampson et al. 1999
Limni Vougliameni	1	Attica	South Core	Pinhasi et al. 2005
Marathon	3	Attica	South Core	Fishman et al. 1977
Megalo Varathro Asteriou, Kaisariani	1	Attica	South Core	Facorellis 2013; Hedges et al. 1993a; ORAU 2016 (ORAU db)
Merenda, Markopoulo	4	Attica	South Core	Maniatis et al. 2016
Vravrona	1	Attica	South Core	Facorellis 1996
Aghia Triadha, Karystos	8	Central Greece	South Core	Facorellis 2013; Maniatis et al. 2016; Mavridis and Tankosic 2009
Corycian Cave, Parnassos	3	Central Greece	South Core	Delibrias et al. 1974; Facorellis 2013; Hinz et al. 2012 (RADON db); Pinhasi et al. 2005; Sampson et al. 1999
Delfi	2	Central Greece	South Core	Facorellis 1996
Elateia	7	Central Greece	South Core	Brami and Zanotti 2015; Facorellis 2003; Hinz et al. 2012 (RADON db); Perlès 2001; Reingruber and Thissen 2005; Vogel and Waterbolk 1963; Weinberg 1962; Weninger 2017 (CalPal db)
Eutresis, Boeotia	3	Central Greece	South Core	Arvaniti and Maniatis 2018; Caskey and Caskey 1960; Johnson 1999; Manning 1995; Manning et al. 2015 (EUROEVOL db); Ralph and Stuckenrath 1962; Renfrew 1971; Sampson et al. 1999; Warren 1976; Weninger 2017 (CalPal db)
Franchthi Koilada Bay	5	Central Greece	South Core	Brami and Zanotti 2015; Reingruber and Thissen 2005
Halai	23	Central Greece	South Core	Brami and Zanotti 2015; Facorellis and Coleman 2012; O'Neill et al. 1999; Reingruber and Thissen 2005; Weninger 2017 (CalPal db)
Kalapodi, Phokis	6	Central Greece	South Core	Toffolo 2013; Weninger 2017 (CalPal db)
Karystos, Euboea	1	Central Greece	South Core	Van Strydonck and De Roock 2017 (Kikirpa db)
Lefkandi, Euboea	15	Central Greece	South Core	Kutschera and Stadler 2000; Linick 1977; Manning 1995; Manning and Weninger 1992; Toffolo 2013; Weninger 2017 (CalPal db)
Proskynas	8	Central Greece	South Core	Higham et al. 2011
Sarakenos cave, Akraifnio, Boeotia	41	Central Greece	South Core	Facorellis 2013; Kaczanowska et al. 2016; Sampson et al. 1999; Sampson et al. 2011
Skotini cave, Euboea	12	Central Greece	South Core	Facorellis 1996; Facorellis 2013; Hinz et al. 2012 (RADON db); Manning et al. 2015 (EUROEVOL db); Pinhasi et al. 2005; Sampson 1993; Sampson et al. 1999; Shennan and Steele 2000; Weninger 2017 (CalPal db)
Tharrounia	11	Central Greece	South Core	Hinz et al. 2012 (RADON db); Manning et al. 2015 (EUROEVOL db); Pinhasi et al. 2005; Reingruber and Thissen 2016 (14SEA db); Weninger 2017 (CalPal db)
Toumba Balomenou, Chaeronea	3	Central Greece	South Core	Facorellis 1996
Aghios Dimitrios, Lepreon	2	Peloponnese	South Core	Johnson 1999; Zachos 1987

Aghios Stefanos, Lakonia	16	Peloponnese	South Core	Hurst and Lawn 1984; Manning 1988
Alepotrypa, Diros	8	Peloponnese	South Core	Bronk Ramsey et al. 2015
Ampelaki-Klaraki, Arcadia	10	Peloponnese	South Core	Arvaniti and Maniatis 2018
Asine, Argolid (Acropolis)	20	Peloponnese	South Core	Håkansson 1983; Macheridis 2016; Manning and Weninger 1992
Asine, Argolid (East cemetery)	12	Peloponnese	South Core	Voutsaki et al. 2010
Aspis, Argos	4	Peloponnese	South Core	Voutsaki et al. 2006
Corinth	5	Peloponnese	South Core	Toffolo 2013; Weninger 2017 (CalPal db)
Franchthi Cave	66	Peloponnese	South Core	Brami and Zanotti 2015; Buckley 1976; Catling 1978; Demoule and Perles 1993; Facorellis 2003; Facorellis 2013; Facorellis and Vardala-Theodorou 2015; Fishman et al. 1977; Hinz et al. 2012 (RADON db); Jacobsen and Farrand 1987; Johnson 1999; Lawn 1971; Lawn 1974; Lawn 1975; Manning et al. 2015 (EUROEVOL db); Mee et al. 2014; Perlès 2001; Perlès et al. 2013; Reingruber 2015; Reingruber and Thissen 2005; Reingruber and Thissen 2009; Sampson et al. 1999; Trantalidou 2014; Weninger 2017 (CalPal db)
Geraki	1	Peloponnese	South Core	Arvaniti and Maniatis 2018
Halieis, Argolid	5	Peloponnese	South Core	Lawn 1975
Helike	1	Peloponnese	South Core	Soter and Katsonopoulou 2011
J. Paul Getty Museum, Malibu	1	Peloponnese	South Core	Berger and Protsch 1989
Klissoura 1 Cave	3	Peloponnese	South Core	Koumouzelis et al. 2001; Trantalidou 2014
Kouphovouno, Lakonia	46	Peloponnese	South Core	Arvaniti and Maniatis 2018; Cavanagh et al. 2016; Mee et al. 2014; ORAU 2016 (ORAU db); Reingruber and Thissen 2016 (14SEA db); Vaiglova et al. 2014
Kouveleiki Cave I, Alepohori, Lakonia	7	Peloponnese	South Core	Facorellis 1996; Facorellis 2013; Sampson et al. 1999
Kouveleiki Cave II, Alepohori, Lakonia	4	Peloponnese	South Core	Facorellis 2013; Sampson et al. 1999
Lerna, Argolid	29	Peloponnese	South Core	Arvaniti and Maniatis 2018; Engstrand 1967; Hinz et al. 2012 (RADON db); Kohler and Ralph 1961; Manning 1995; Manning et al. 2015 (EUROEVOL db); Mee et al. 2014; Ralph and Stuckenrath 1962; Renfrew 1971; Vitelli 2007; Voutsaki et al. 2010a; Warren 1976; Weninger 2017 (CalPal db)
Limnes (Lakes) Cave, Kastria Kalavryta	10	Peloponnese	South Core	Facorellis 1996; Facorellis 2013; Facorellis and Maniatis 1997; Mee et al. 2014; Pinhasi et al. 2005; Sampson et al. 1999
Midea, Argolid	4	Peloponnese	South Core	Engstrand 1965; Hedges et al. 1993b; Hinz et al. 2012 (RADON db); Kutschera and Stadler 2000; Manning and Weninger 1992

Mycenae	7	Peloponnese	South Core	Gillespie et al. 1985; Hinz et al. 2012 (RADON db); Kutschera and Stadler 2000; Lawn 1970; Manning and Weninger 1992; Zouridakis et al. 1987
Nichoria, Messenia	15	Peloponnese	South Core	Kutschera and Stadler 2000; Manning and Weninger 1992
Papoulia Tumulus	1	Peloponnese	South Core	Hurst and Lawn 1984
Pylos	14	Peloponnese	South Core	Hinz et al. 2012 (RADON db); Kutschera and Stadler 2000; Manning and Weninger 1992; Ralph and Stuckenrath 1962; Zouridakis et al. 1987
Sanctuary of Zeus, Mt. Lykaion, Arcadia	76	Peloponnese	South Core	Starkovich et al. 2013
Tiryns	3	Peloponnese	South Core	Zouridakis et al. 1987
Tsoungiza, Nemea	13	Peloponnese	South Core	Arvaniti and Maniatis 2018; Bronk Ramsey et al. 2004; Höflmayer 2010; Johnson 1999; Manning et al. 2006
Aghia Irini, Keos	11	South Aegean	South Core	Betancourt et al. 1978; Fishman and Law 1978; Manning 1988; Stuckenrath and Lawn 1969
Kephala, Keos	1	South Aegean	South Core	Coleman 1977; Johnson 1999; Manning et al. 2015 (EUROEVOL db); Renfrew 1971; Sampson et al. 1999; Stuckenrath and Lawn 1969; Tomkins 2007; Weninger 2017 (CalPal db)
Thermo	7	Western Greece	South Core	Facorellis 1996

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SUPPLEMENTAL MATERIAL

Long-term trends of land use and demography in Greece: a comparative study

Weiberg, E., A. Bevan, K. Kouli, M. Katsianis, J. Woodbridge, A. Bonnier, M. Engel, M. Finné, R. Fyfe, Y. Maniatis, A. Palmisano, N. Roberts, S. Shennan

Supplementary Table 2. Metadata for pollen assemblages from Greece used in the present study (the site numbers refer to the numbering in **Figure 1b,** giving the geographical locations of the pollen assemblages used).

#site	Site	N/S	Site code	Latitude	Longitude	Altitude	Contributor	Site type	References
1	Edessa	N	EDESSA	40,818056	21,9525	350	EPD	marsh	Bottema, 1974 *
2	Flambouro-Pieria mountains	N	PIERIA	40,259444	22,170833	1645	EPD	bog	Gerasimidis and Panajiotidis, 2010 *
3	Giannitsa	N	GIANNITB	40,666667	22,316667	20	EPD	small lot in cultivated plain	Bottema, 1974 *
4	Ioannina	N	IOAN249	39,65	20,916667	470	EPD	lake	Tzedakis, 1994 *
		N	IOANNINA	39,7625	20,730556	470	EPD	marshland and cultured land	Bottema, 1974 *
5	Kastoria	N	KASTORIA	40,551944	21,322222	650	EPD	lake with large swamp	Bottema, 1974 *
6	Khimaditis	N	KHIMADIT	40,616667	21,583333	560	EPD	marshy plain	Bottema, 1974 *
		N	KHIMAIII	40,6125	21,586111	560	EPD	lake	Bottema, 1974 *
7	Lake Gramousti	N	GRAMOU	39,885	20,595278	400	EPD	lake drained in 1961	Willis, 1992a *
8	Lake Maliq	N	MALIQS1	40.766667	20.783333	81	EPD	drained lake	Denèfle et al., 2000 *
9	Lake Orestiás	N	ORESTG25	40,511667	21,257778	630	EPD	lake	Kouli and Dermitzakis, 2010 *
10	Lake Xinias	N	XINIAS	39,05	22,266667	500	EPD	lake	Bottema, 1979*
11	Litochoro	N	LITOCHOR	40,138889	22,546111	25	EPD	large marsh	Athanasiadis, 1975 *
12	Mount Paiko	N	PAIKO	41,051667	22,274722	1080	EPD	peat bog	Gerasimidis and Athanasiadis, 1995 *
13	Mount Voras	N	VORAS	41,019722	21,912222	1640	EPD	mire	Gerasimidis and Athanasiadis, 1995 *

14	Nisi Fen	N	NISIB	40,816667	21,916667	475	EPD	fen	Lawson et al., 2005 *
		N	NISIE	40,816667	21,916667	475	EPD	fen	Lawson et al., 2005 *
15	Pertouli	N	PERTOYLI	39,524167	21,4775	1440	EPD	peat bog	Athanasiadis, 1975 *
16	Rezina marsh	N	REZINA	39,987778	20,775556	1760	EPD	marsh	Willis, 1992b *
17	Tristinika	N	TRISTINIKA	39,99917	23,87444	0	Panagiotidis	coastal marsh	Panajiotidis and Papadopoulou, 2016
18	Vegoritis	N	VEGORIT	40,75	21,75	570	EPD	lake	Bottema, 1974 *
19	Aghia Galini	S	GALINI	35,1	24,683333	0	EPD	coast	Bottema, 1990 *
20	Akovitika	S	AKOVITIKA	37,03518	22,07829	0	Engel	archaeological site	Engel et al., 2009
21	Asi Gonia	S	ASIG1	35,248611	24,277778	780	EPD	peat bog	Atherden and Hall, 1999 *
		S	ASIG2	35,248611	24,277778	780	EPD	peat bog	Atherden and Hall, 1999 *
22	Elefsis	S	ELEFSIS	38,000139	23,463	-35	Kouli	bay	Kyrikou, 2016; Kyrikou et al., 2016
23	Halos	S	HALOS	39,166667	22,833333	0	EPD	coastal marsh	Bottema, 1988 *
24	Kopais	S	KOPAIS	38,483333	23,066667	10	EPD	lake	Turner and Greig, 1975 *
25	Lake Lerna	S	LERNA	37,583333	22,75	0	EPD	ancient lake	Jahns, 1993 *
26	Lake Voulkaria	S	VOULKARI	38,866667	20,833333	0	EPD	lake	Jahns, 2005 *
27	Trikhonis	S	TRIKHON5	38,6	21,5	20	EPD	lake	Bottema, 1982 *
28	Vravron	S	VRAVRON	37,925517	23,999967	0	Kouli	marsh	Kouli, 2012

* Original reference but data retrieved from EPD (www.europeanpollendatabase.net/)

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SUPPLEMENTAL MATERIAL

Long-term trends of land use and demography in Greece: a comparative study

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Supplementary Table 3. Datasets used for the compilation of archaeological site data from the Peloponnese and Macedonia (**Figs. 4-5**). Letters (A-M) refer to **Figure 1b** where the geographical location of the surveyed areas are indicated.

	Dataset	Location	Sites	Site phases	Type	Year of study	Focus	Reference
	SOUTH	**Peloponnese**						
A	Asea Valley	Arcadia	53	240	I	1994–1996	All	Forsén and Forsén, 2003
B	Berbati-Limnes (incl. Mastos)	Argolid	92	277	I	1988–1990 (1999)	All	Wells and Runnels, 1996 (Lindblom and Wells, 2011)
C	Methana	Argolid	93	548	I	1984–1986	All	Mee and Forbes, 1997
D	Southern Argolid	Argolid	252	819	I	1979–1982	All	Jameson et al., 1994
E	Phlious Valley	Corinthia	59	268	I	1998–2002	All	Casselmann et al., 2004
F	Pylos region	Messenia	49	406	I	1991–1995	All	Davis et al., 1996
	Total		***598***	*2558*				
	NORTH	**Macedonia**						
G	Anthemountas	Central	26	94	I	2010–2015	Prehistory	Andreou et al., 2011; Siounta, 2017
H	Central Macedonia	Central	243 (214)*	599 (533)*		1967–1996	Prehistory	Grammenos et al., 1997
I	Sithonia	Central	13	29	E	1999–2001	Prehistory	Smagas, 2007
J	Sithonia Intensive	Central	46	76	I	2002–2004	Prehistory	Smagas, 2007
K	Aliakmon	West	216	297	E/I	1985–	All	Chondrogianni-Metoki, 2015
L	Kitrini Limni, Kozani	West	47	119	E	1985–	Prehistory	Karamitrou-Mentessidi, 2014
M	Langadas	West	75 (86)*	145 (122)*	I	1986–1997	All	Andreou and Kotsakis, 1999
	Total		***637***	***1270***				

* In the Langadas survey a total of 86 sites were identified, but since 11 of these were also noted by Grammenos et al. (1997) the equivalent number of periods were subtracted from the Langadas total; in Central Macedonia a total of 243 were identified, of which 27 were noted also by the Anthemous Valley Archaeological Project (12) and the Sithonia Surveys (15) and hence subtracted from the Central Macedonia total.

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