SVENSKA INSTITUTEN I ATHEN OCH ROM
INSTITUTUM ATHENIENSE ATQUE INSTITUTUM ROMANUM REGNI SUECIAE

Opuscula

Annual of the Swedish Institutes at Athens and Rome

15
2022

STOCKHOLM

SECRETARY'S & EDITOR'S ADDRESS
Department of Archaeology and Classical Studies
Stockholm University
106 91 Stockholm, Sweden
secretary@ecsi.se | editor@ecsi.se

DISTRIBUTOR
Eddy.se AB
Box 1310
621 24 Visby, Sweden

For general information, see http://ecsi.se
For subscriptions, prices and delivery, see http://ecsi.bokorder.se
Published with the aid of a grant from The Swedish Research Council (2020-01217)
The English text was revised by Rebecca Montague, Hindon, Salisbury, UK

Opuscula is a peer reviewed journal. Contributions to *Opuscula* should be sent to the Secretary of the Editorial Committee before 1 November every year. Contributors are requested to include an abstract summarizing the main points and principal conclusions of their article. For style of references to be adopted, see http://ecsi.se. Books for review should be sent to the Secretary of the Editorial Committee.

ISSN 2000-0898
ISBN 978-91-977799-4-4

Printed by PrintBest (Viljandi, Estonia) via Italgraf Media AB (Stockholm, Sweden) 2022
Cover illustrations from Peter M. Fischer & Teresa Bürge in this volume, p. 48

ERIKA WEIBERG & MARTIN FINNÉ

Human-environment dynamics in the ancient Mediterranean

Keywords of a research field

Abstract

Human-environment dynamics in past societies has been a major field of research in the Mediterranean for a long time, but has grown significantly following the increase in the number and quality of palaeoclimate and palaeoenvironmental records in the last two decades. Here we sketch the outline of this field of research based on 1,531 author keywords from 280 peer-reviewed articles published in 78 different scientific journals during 2016–2021. Sourced from the *Web of Science*, the selected studies cover the time span from the Neolithic to the Roman period across the Mediterranean and provide a large number of entry points for the interested reader regardless of their prior knowledge and specific interests. The results make evident the breadth and interdisciplinary nature of this research and show that it is possible to approach questions of human-environment dynamics in many and diverse ways. Among other things, our overview outlines the importance of temporal and spatial scales, as well as the elusive nature of causality, and highlights that monocausal models connecting climate events and societal collapse are increasingly replaced by scenarios favouring more nuanced renditions of the sequence of events within which internal societal factors are given more room for play.*

Keywords: human-environment dynamics, ancient societies, Mediterranean, climate, systematic review, *Web of Science*, keywords

https://doi.org/10.30549/opathrom-15-07

Introduction

Human-environment dynamics in past societies has been a major field of research in the Mediterranean for a long time, with new lines of research and increased level of detail being added continuously. Erosion and landscape evolution were prominent early topics, and environmental mapping has been a part of most field archaeological survey projects.[1] Considerations of climate were a natural part of these discussions but initially, when palaeoclimate proxy records were few, climate of the past was addressed on a hypothetical level or with reference to modern conditions or ancient textual records. In parallel with a growing concern for current-day global environmental change, the last two decades have seen a significant increase in the number and quality of palaeoclimate and palaeoenvironmental records, enabling closer analyses of specific climate, environmental and societal anomalies. The level of integration between different types of data, and between researchers of different disciplines, has also increased significantly during the same time but especially during the last decade, along with a growing understanding of the complexities of human-environment dynamics. It is fair to say that research on human-environment dynamics in past societies has exploded over the last decade and the Mediterranean is no exception.

The challenges we face today in terms of environmental and climate change are manifold, not least in the Mediterranean, which, for example, is projected to lose a substantial amount of the present-day winter precipitation that is so vital for the region.[2] These challenges raise new questions and issues for our current-day society but also for scholars of past human-environment dynamics. The question is if and how knowledge of the past can provide clues for the present and

* The authors gratefully acknowledge the funding from the Swedish Research Council (grant no. 2019-02868) for the project *Climate and ancient societies in Bronze Age Peloponnese* (CASE, PI: Erika Weiberg). We also thank the Editorial Committee of the Swedish Institutes at Athens and Rome for the opportunity to write this review. It has been a great learning experience in many ways and an inspiration towards further engagement with the topic of human-environment dynamics, both within the Peloponnese and beyond.

[1] Bintliff 2002; Butzer 2005; Izdebski *et al*. 2016; Knapp & Manning 2016, all with further references.

[2] Lionello & Scarascia 2018; Tuel & Eltahir 2020, 5829 (locally up to 40% reduction).

future,[3] but also how current issues and concerns can open up new frameworks of research and provide new ways of approaching past human-environment dynamics. A crowd-sourcing enterprise ten years ago resulted in a list of 25 grand challenges for archaeology to tackle the next 25 years.[4] The challenges were organized into five topics, two of which are of primary interest for human-environment dynamics: "resilience, persistence, transformation and collapse" and "human-environment interactions". The questions/challenges posed in the former related to the differential persistence of societies, the "roles of social and environmental diversity and complexity in creating resilience and how do their impacts vary by social scale", and definitions of social collapse as well as any signs forewarning it.[5] The second topic entailed the scale and timing of human impacts on the environment, drivers of population growth and health and well-being in ancient societies, human response to abrupt environmental change (mentioning tsunamis, earthquakes, volcanic eruptions, short-term weather events, and wildfires), as well as the perception of and response to climate and environmental change.[6] Although not clearly stated, these are topics clearly anchored within current concerns for the future of our own society, and there are many parallels to be found with the 17 sustainable development goals set up by the UN in 2015, for full implementation by 2030.[7] Moreover, although crafted with reference to archaeology, meeting many of the 25 challenges would entail more intensive collaboration across disciplines.[8] The challenges listed by Kintigh *et al*. also find many parallels with the 50 priority research questions put forward for palaeoecology[9] as well as for historical ecology.[10] These two additional crowd-sourcing efforts have also pinpointed the need to address different temporal and spatial scales to deal with uncertainties and to find workable methods and tools to manage for comparability between records within and between disciplines.[11] The three crowd-sourcing attempts to define common questions are now five years old or more. The question is how studies of human-environment dynamics in the Mediterranean have managed to answer these open questions, even if not in direct response to the original crowd-sourcing enterprise.

In order to capture the content of the very expansive field of human-environment dynamics research, the present article revolves around a bibliometric-based selection of research articles on human-environment dynamics in the Mediterranean since 2016.[12] The results make evident the breadth of research and show that it is possible to approach questions of human-environment dynamics in many and diverse ways. Moreover, the overview provides a large number of entry points for the interested reader regardless of their prior knowledge and specific interests. In order to explore both the depth as well as the breadth of the research field, the present article is a study in two parts. In the first part, the method and basic parameters of the bibliometric overview are presented, followed by an analysis of the patterns provided by the keywords chosen by the authors of each of the articles selected for the overview. The general composition of these keywords pinpoints the primary avenues of research during the last six years. In the second part, we delve into the details of some of the studies and focus specifically on key analytical concepts for understanding change across time and space. The aim of the second part is to provide glimpses of current research thematics from diverse environmental settings located around the Mediterranean. In combination with the analysis of keywords, these brief insights into current projects provide an opportunity to take the pulse of human-environment dynamics research in relation to the highlighted calls for action. Here, special attention is paid to the contribution of different disciplines to the study of human-environment dynamics and to interdisciplinary collaboration on these topics.

Material and methods

The bibliometric analysis is based on articles derived from the *World of Science* (*WoS*) database,[13] and three general criteria

---

[3] See e.g. efforts within Past Global Changes (PAGES, www.pastglobalchanges.org) and *Integrated History and future of People on Earth* (IHOPE, www.ihopenet.org).

[4] Kintigh *et al.* 2014. The crowd-sourcing effort was started online in the spring 2012 and followed by a workshop the same year.

[5] Kintigh *et al.* 2014, 11–12.

[6] Kintigh *et al.* 2014, 15–19.

[7] United Nations 2015.

[8] Kintigh *et al.* 2014, 19.

[9] Seddon *et al.* 2014, resulting from a workshop in 2012.

[10] Armstrong *et al.* 2017, drafted during workshops in 2014 and 2015.

[11] Seddon *et al.* 2014, 263; Armstrong *et al.* 2017, 7–8.

[12] Despite an extensive bibliography, this review leaves out a significant number of recent publications relevant to the topic. Some additions are made in order to look back in time or beyond the boundaries of the present review, but the content as well as in-text references are dominated by articles that were selected through our bibliometric search. Cited articles that are *not* among the selected articles are marked by an asterisk (*) in the bibliography. It should also be noted that not all of the selected articles are cited; those that are cited represent examples of the outlined research trends. Full details of the selected articles can be found in *Supplemental information* at https://doi.org/10.30549/opathrom-15-07.

[13] *Web of Science Core Collection* 2021. According to the information provided by the Web of Science Core Collection, the collection contains articles from over 21,100 peer-reviewed journals published worldwide and these journals cover more than 250 disciplines in natural sciences, social sciences, and arts and humanities (Clarivate 2021: https://clarivate.com/webofsciencegroup/solutions/web-of-science-core-collection/). A study of the use of *WoS* for research articles and review articles (Li *et al.* 2018, 5–6) shows that *WoS* plays an important role in the overall academic com-

were used to make the corpus of articles manageable. We have not wanted to single out any specific part of the Mediterranean or focus specifically on a limited time period. The criteria related to chronology and geography are therefore broadly set. This study deals with the human-environment dynamics from Neolithic to Roman times across the full circumference of the Mediterranean (with a delimitation set roughly at 300 km inland from the coastline of the Mediterranean Sea). The beginning of the time period in absolute years differs with the timing of the onset of the Neolithic period in each region but the end is set to *c.* AD 300. Studies with a primary focus on the Palaeolithic and Mesolithic Mediterranean as well as the Late Roman (and later periods) have been excluded. Fortunately, there are several recent reviews of human-environmental studies focusing on later historical periods that may serve to close this latter gap.[14] A third general criterion is of topical nature and based on our understanding of "research on human-environment dynamics" as research with a clear interdisciplinary intent that aims to give focus to both humans and the environment, and the linkages between the two, even if an equal balance is not achieved. Special emphasis is put on climate-related studies, reflecting the expertise of the present authors as well as the common concern for climate change effects on the persistence of human societies today.

The bibliometric search was conducted on 27 September 2021, and includes articles published from January 2016 up to the day of the search.[15] The searches were directed towards the content of the "Title", "Author keyword", "*WoS* Keywords Plus" (generated from the items cited in each article), and the "Abstract". In all, 19 English-language search strings were used, all encompassing "climate" in combination with one geographical determinant ("Mediterranean", "Spain", "Italy", "France", "Greece", "Aegean", "Turkey", "Syria", "Lebanon", "Israel", "Levant"), as well as one of the chronological determinants: "Ancient history", "Antiquity", "Bronze Age", "Neolithic", "Classical archaeo*" "Roman", "Greek", or, one of the keywords "Archaeo*" or "Human-environment". The North African countries along the south coast were not searched individually, but studies of this region appeared among those tagged with "Mediterranean". The selection of *WoS* and these specific search strings was a measure to facilitate easy access and relative speed in the analysis, but also a way to delimit the number of records. Even with these delimitations, the 19 search strings resulted in 1,301 articles, which decreased to 776 articles after the deletion of duplicates. The 776 articles were thereafter sorted based on chronology, geography and overall topic according to the criteria listed above. Articles falling outside the chronological (Neolithic to Roman) and geographical (Mediterranean) scope of the present study and articles without an interdisciplinary intent were removed. The final list includes a total of 280 articles spread across 78 journals (*Supplemental information*, see https://doi.org/10.30549/opathrom-15-07). The use of English-language search strings and thereby the exclusion of non-English articles as well as other types of publications (articles in non-indexed journals, monographs, edited books, book chapters, etc.) was necessary to limit the data. The result may therefore be biased in terms of language and type of publication. Importantly, however, the results likely encompass a broader and more diverse corpus of publications than would have been the case if a selection was made on the basis of the prior knowledge of the authors of the present review or the citation repertoire in individual articles.

Part one: outline of a research environment

The bibliometric overview provides a picture of a productive and diverse research field. The overall output of the 280 articles has been roughly equal between the years since 2016, with a notable drop in 2020, which would seem to be an effect of the pandemic (*Fig. 1A*). All these articles combined represent a scholarly group of 1,264 unique authors. A large majority (78%) of these authors have only contributed to one article, and authors contributing to three or more articles make up only 10% of the total number of authors. The gender distribution among the lead authors is relatively balanced (60/40 in favour of male lead authors). This balance changes to 70/30 (in favour of male-led) when considering the top 40 scholars who have contributed to most articles. The numbers clearly outline a very broad interest in human-environment dynamics, but also a field of study that is primarily driven by a more limited number of scholars.

In order to explore the thematics among the corpus, the "Author keywords" of the selected articles were analysed for

munity and the number of review articles utilizing the platform has steadily increased since the beginning of the 21st century, showing the importance of *WoS* and *WoS* data "to find new research areas based on existing efforts" (Li *et al.* 2018, 6). The usefulness of other databases and/or data-search engines (e.g. *Google Scholar*) to cover broad topics and large geographical areas is demonstrated by Moreno-de-las-Heras *et al.* (2019) and Ljungqvist *et al*. (2021).

[14] Xoplaki *et al.* 2016; Decker 2017; Haldon & Rosen 2018; Marx *et al.* 2018; Sessa 2019; Huhtamaa & Ljungqvist 2021; Ljungqvist *et al.* 2021.

[15] The start date of the search period is linked to the publication of the special issue *Mediterranean Holocene climate, environment and human societies*, edited by Alexandra Gogou, Adam Izdebski and Karin Holmgren, and published in *Quaternary Science Reviews* in March 2016 (Gogou, Izdebski & Holmgren 2016). The special issue was a direct result of an influential workshop held at the Navarino Environmental Observatory (NEO), Costa Navarino, Greece, in April 2014 with participants from 16 countries. It marks the decisive move by the workshop participants to engage in better scientific integration and all papers were co-authored by scientists representing different disciplines.

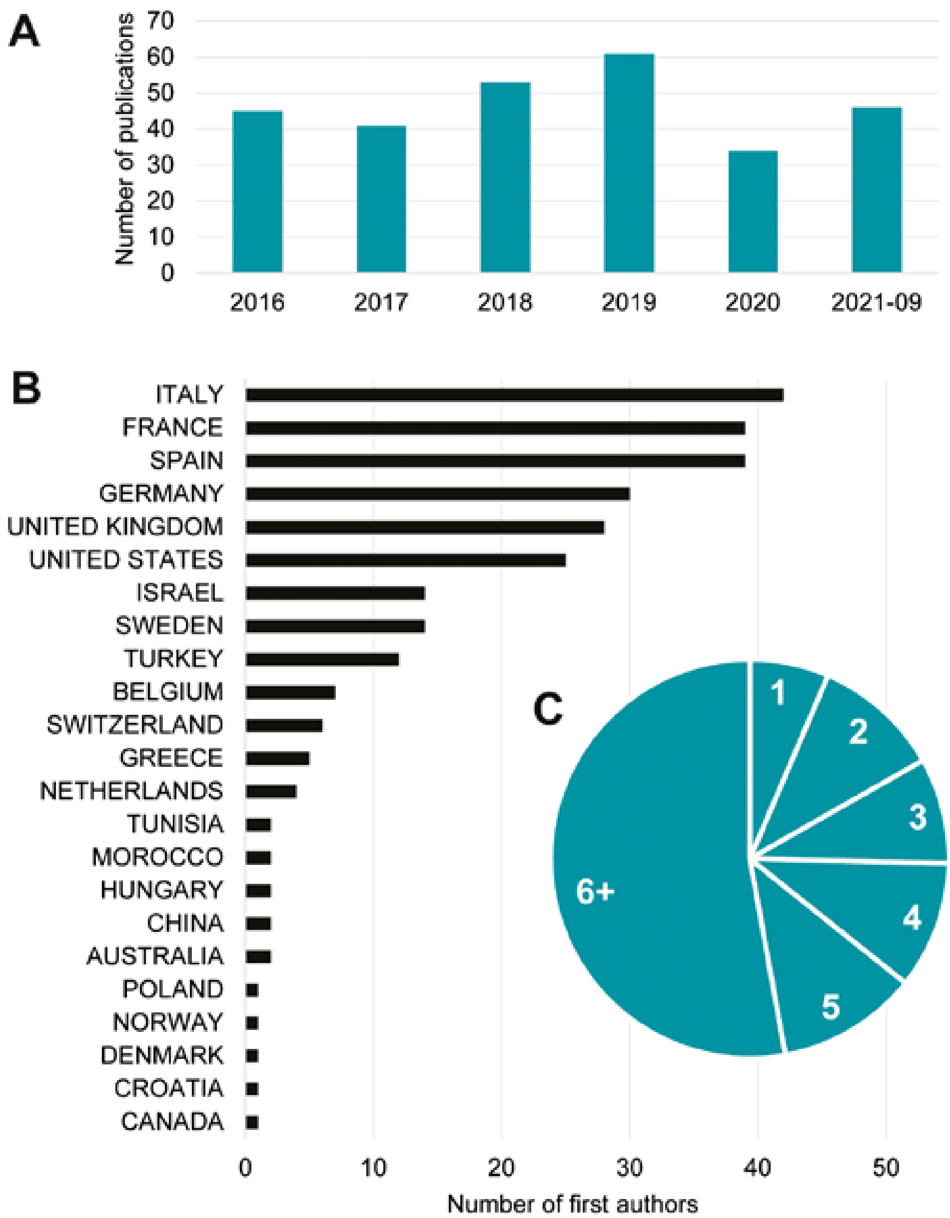

Fig. 1. Considerations of a research environment, including (A) the number of articles per year (2021 only up to 27 September), (B) the country of affiliation of the first authors, and (C) the number of authors per article. Illustration by E. Weiberg and M. Finné.

content and research foci (*Fig. 2*) in an approach similar to that of Pesta *et al.*[16] Not all journals use author keywords and 44 articles were thereby excluded from this part of the exercise, leaving 236 articles and a total of 1,531 keywords, resulting in 817 unique keywords.[17] These unique keywords were first categorized according to seven general categories: Geography, Discipline, Chronology, Method, Archive, Proxy, and Topic, and thereafter into subcategories to explore the variability (for

[16] Pesta *et al.* 2018, 2, 11. Author keywords represent the most important *c.* five words in an article based on the opinion of the authors and can be used to detect common and perhaps trending research topics.

[17] The number of separate keywords counted after standardization of variabilities due to spelling, singular/plural use or the use of abbreviations. Articles with and without keywords are specified in *Supplemental information* at https://doi.org/10.30549/opathrom-15-07.

full details, see *Appendix*). The author keywords do not give a full picture of the content but serve to gauge the central points of the articles from the perspective of the authors. The following sections will use the seven general categories to sketch the outline of the research environment dedicated to the study of human-environment dynamics in the Mediterranean from the Neolithic period to the Roman era.

GEOGRAPHY

Keywords denoting the geographical focus (n=255) of the studies illustrate the pan-Mediterranean perspective of the present review. A majority of the keywords are rather general, defining the studied region in relation to relatively large geographical areas, such as the whole or parts of the Mediterranean (n=43), or modern countries and parts thereof (for details, see *Appendix*). Although less common, a number of studies nevertheless are considerably more local and even in a few examples linking to one site specifically, such as Arslantepe, Kultepe, Petra, Phaistos, Pompeii and Utica.[18] Overall there is a reasonable balance between different parts of the Mediterranean, although with some dominance of its central and eastern parts. The facts that we used English-language search strings did not have any clear effect on the affiliation of the authors. Rather than an Anglo-Saxon academic environment of the authors, the top affiliations are: Italy, France and Spain (*Fig. 1B*). A second group comprised Germany, the United Kingdom and the United States. Given the prominence of these countries in most fields of research, the composition of this second ground was an expected outcome, but that these three are followed by Israel and Sweden is noteworthy. Israel-led projects may perhaps be put down to geography and relatively high per capita research funding.[19] The Swedish contributions, on the other hand, testify to a long research history in Greece, and in the Peloponnese particularly, and more recently to a strong research environment of collaborative efforts focused on human-environment dynamics, initiated by an innovative and very consciously interdisciplinary research effort in 2008 that led on to multiple research projects.[20] There are only a handful of lead authors with a Greek affiliation, although keywords belonging geographically to the Balkans—predominantly Greece—are the most common. Case-studies from Iberia (predominantly Spain) and Italy are also common and can in some respect be correlated with the frequency of lead author affiliations. Near Eastern and Anatolian case-studies are only partially correlated with the affiliations, signifying, as in the case of Greece, a considerable degree of international involvement, something that is the most apparent among the southern Mediterranean/north African case-studies. Importantly, these conclusions are based on the affiliation of the lead authors and not their actual nationalities and do therefore not capture academic mobility in either direction.[21]

DISCIPLINE AND CHRONOLOGY

Human-environment dynamics is a topic that brings together a large number of disciplines, a circumstance that is clearly evident among the selected articles. Here we use "discipline" in a loose sense, denoting separate fields of research that are either academic disciplines, such as archaeology, or subdisciplines, such as archaeobotany, which is commonly regarded as a subdiscipline of archaeology. The keywords denoting a "discipline" are tied to specific interests, materials and scientific approaches but commonly also have an effect on chronological perspectives as well as the choice of journals and the size of the author groups.[22]

All in all, 168 keywords were deemed to reflect a discipline (see details in *Appendix*), divided into the subcategories of *Humanities and Social sciences*, *Natural science*, and *Intermediate*, the latter of which is tied together by a concern for the reconstruction of cultural landscapes from an environmental perspective. The Humanities and Social science subcategory of articles is dominated by keywords relating to the discipline of archaeology with only three keywords tied to the history discipline. "Archaeology" is in fact the most common individual keyword in this subcategory, followed by "geoarchaeology", "palynology" and "archaeobotany" in the Intermediate subcategory. The Natural science subcategory is more fragmented and "palaeoclimatology", for example, is less frequent than might be expected given the search strings, but this is offset by the high frequency of keywords related to palaeoclimate and climate change. The low frequency of "history" as a keyword, however, deserves special consideration. To some extent this outcome is expected. Via our search strings, we have favoured archaeological studies, and, we have excluded later historical periods (later than *c.* AD 300). Still, it is a noted fact that archaeologists and archaeological per-

18 Bouchaud *et al.* 2017; Ghilardi *et al.* 2018; Masi *et al.* 2018; Şenkul *et al.* 2018; Pleuger *et al.* 2019; Vignola *et al.* 2021.

19 OECD n.d.

20 Sinclair *et al.* 2010. We would like to extend our gratitude to the directors of this effort—the *Urban Mind* project—Professors Gullög Nordquist and Paul Sinclair, Department of Archaeology and Ancient History, Uppsala University, who brought the current authors together and set us on the way towards interdisciplinary collaborations in general and human-environment dynamics in particular.

21 Only the first-mentioned affiliation was included and although some authors have double affiliations, or more, these are a minority and most relate to institutions in the same country.

22 Izdebski *et al.* 2016, 16–17.

spectives have dominated in interdisciplinary collaborations on human-environment dynamics and that (ancient) historians have shown less interest in these questions.[23] The lack of studies among our set of articles that focus on the Greco-Roman period—only 10% of the keywords denoting chronology (n=202) indicate a focus on a historical period (*c.* 1000 BC–AD 300)—shows that this is not only a disciplinary gap (archaeologists versus ancient historians) but a notable invisibility of the Greco-Roman period as such in this type of studies. This is not to say that the historical periods are not covered in the present articles. Many of the studies apply long-term chronological perspectives, but compared to the larger quantity of Neolithic and Bronze Age studies, the lack of historical case-studies stands out. The most common chronological indicator is "Holocene", emphasizing the long-term perspectives of many studies, but this particular concept also indicates a natural science bias of these studies. Given the overall dominance of the relative chronology among the chronological keywords (e.g. "Neolithic", "Late Bronze Age", etc.), however, it seems fair to say that a majority of the studies, including the more natural science-oriented ones, are adapted to relative chronologies and periodization used within archaeology.

Turning to the choice of journals, a majority of the studies captured in our search of *WoS* looks beyond the common archaeological outlets. While 26% of the 78 journals are indeed archaeological journals, they have only attracted 19% of the articles included here, and half of these are found in the science-oriented *Journal of Archaeological Science* (*JAS*) and *JAS Reports*. In contrast, 36% of the articles are to be found in three high-ranked, primarily natural-science-based journals: *Quaternary Science Reviews*, *Quaternary International* and *The Holocene*. Archaeology articles typically have a limited number of authors but over half of the articles analysed here list six or more authors, which is more typical of natural sciences. Only 17% of the articles have one or two authors as is more common in archaeological publishing (*Fig. 1C*). The common occurrence of articles with many authors highlights the complexity of many of the studies and their multidisciplinary (if not always interdisciplinary) nature. It also reflects the tradition of natural science publishing, within which e.g. analytical or methodological contributions often merit co-authorship. Publishing in science-based journals has a number of advantages: they have often a quick turn-over time, the addition of supplementary online information is commonplace, and they often have a high-impact factor. From an archaeological point of view, what you lose in terms of intra-disciplinary visibility and disciplinary competence, you gain in interdisciplinary visibility and citations. Archaeologists have a long tradition of multidisciplinary work and archaeology as a discipline incorporates science-based subdisciplines such as geoarchaeology, archaeobotany and zooarchaeology. The threshold for an archaeologist to publish in science-based journals is likely to be considerably lower than for a historian, for example.[24]

METHOD, ARCHIVE AND PROXY

The keywords specifying the type of method employed to investigate past human-environment dynamics in the Mediterranean (n=119) provide an overview of the range of methods used. These are in turn linked to specific archives (n=31), and proxies (indirect indicators) (n=126). Lacustrine and wetland sediments and speleothems (cave stalagmites)—the most-commonly utilized natural archives for palaeoenvironmental and palaeoclimate studies—make up roughly two-thirds of the archive keywords. The vast majority of the proxy keywords can be directly attributed to studies of palaeoenvironments and palaeoclimate and broadly divided into fossils (on-site macrofossils such as seeds and charcoal, but including also charcoal particles, pollen grains and other microfossils from off-site sediment cores) and different types of isotopes (represented by oxygen, hydrogen, nitrogen, strontium and carbon isotopes) (see details in *Appendix*).

The versatility of isotope analysis transcends conventional disciplinary boundaries, its use spanning from palaeoclimate analyses[25] to the study of human population migration.[26] The development during the last decade of stable nitrogen and carbon isotope analyses have allowed for reconstructions of ancient agricultural strategies and palaeodiets.[27] Climate is generally not a direct focus in these studies but implicit through discussions on water availability, or water status conditions, frequently necessitating comparison with palaeoclimate records to sort out natural factors from active water management, either by direct watering or by seeking out more naturally well-watered fields for some crops.[28] Pollen, however, remains the most prevalent proxy for environmental reconstructions, crucial for our understanding of land cover (vegetation) as well as land use. Also here, there has been a considerable method development during the last decade or so, primarily in terms of the inclusion of a wider spectrum of proxies from within the same sediment core, such as biomarkers[29] and micro-charcoal.[30] Such multi-proxy analyses

[23] Izdebski *et al.* 2016; Post 2017; see also Haldon *et al.* 2018.

[24] Izdebski *et al.* 2016, 16–17; Ljungqvist *et al.* 2021, 16.

[25] Finné *et al.* 2019; Surić *et al.* 2021.

[26] Gregoricka & Sheridan 2017.

[27] Bogaard *et al.* 2013; Nitsch *et al.* 2017; Styring *et al.* 2017.

[28] Mora-González *et al.* 2018; Dotsika & Diamantopoulos 2019; Mora-González *et al.* 2019.

[29] Thienemann *et al.* 2017; Norström *et al.* 2018; Katrantsiotis *et al.* 2019.

[30] López-Merino *et al.* 2017; Connor *et al.* 2019; Lestienne *et al.* 2019.

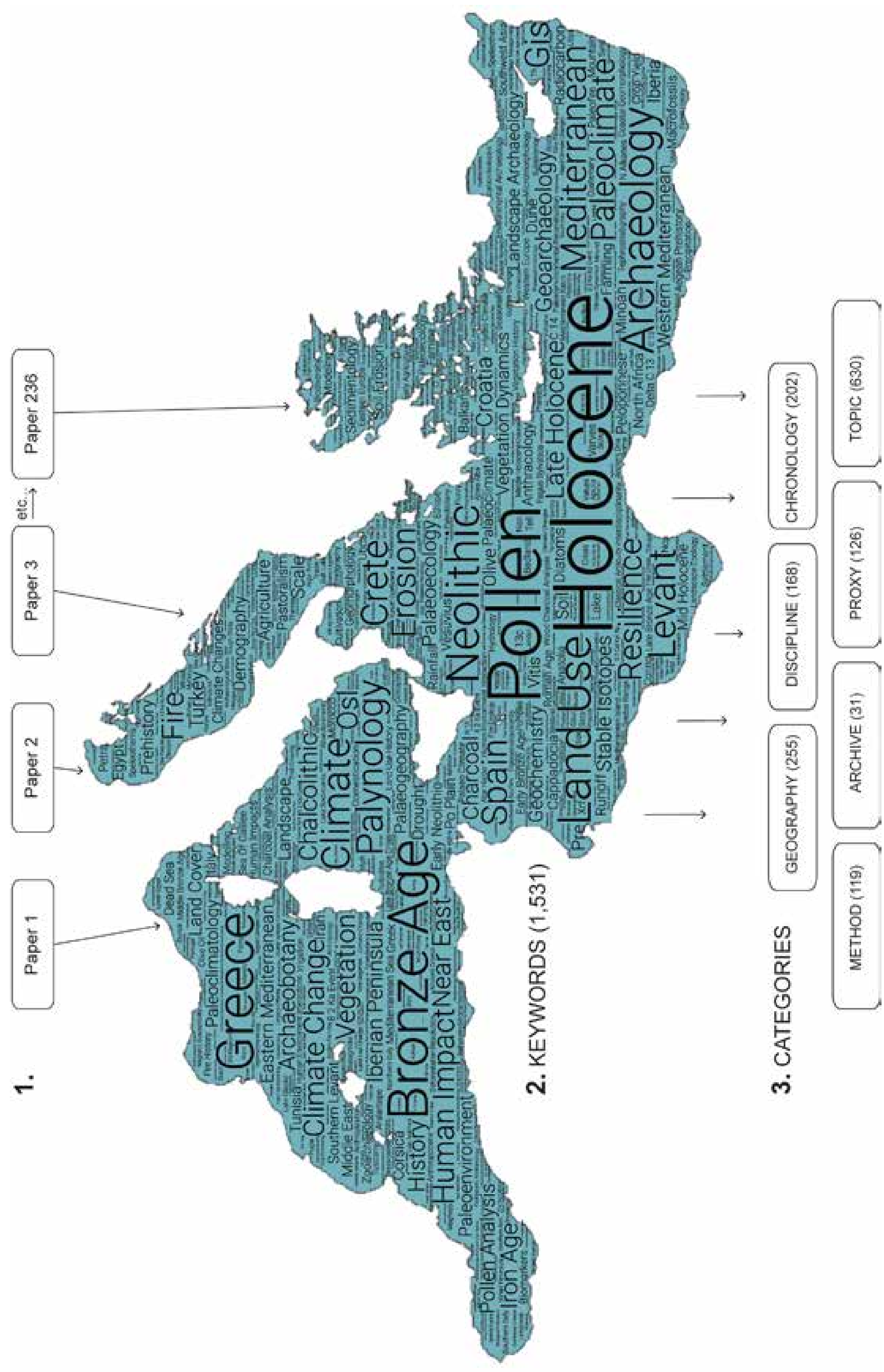

Fig. 2. Illustration of the three-stage keyword method: (1) Selection of articles with author keywords, (2) compilation of all author keywords, and (3) the assignment of the keywords to seven general categories: Geography, Discipline, Chronology, Method, Archive, Proxy, and Topic. The keywords are presented as a word cloud in the shape of the Mediterranean Sea in which the size of each keyword is a visualization of its incidence within the corpus of keywords. Illustration by M. Finné and E. Weiberg.

have been sought after to facilitate chronological correlation between datasets, and are crucial for considerations of causality.[31] But the desire for multi-proxy analyses goes further and brings to the fore the need to establish other datasets, specifically for human activity, as a basis for what can be called multi-*archive* analyses of human-environment dynamics.[32] In that vein, there has been a recent upsurge in numerical methods to investigate demographic change. One such method, summed probability distributions (SPD), utilizes and synthesizes the wealth of radiocarbon dates from the Mediterranean as a population proxy. Results of SPD analyses have been correlated with traditional analyses of settlement patterns using sites identified in field surveys, which remains the most common archaeological proxy for demographic change and for large-scale comparisons with environmental data. These correlations have made clear that radiocarbon SPD have a positive correspondence with patterns based on archaeological site data, and that SPD can be very useful when archaeological settlement data are lacking or for highlighting variability within relative chronologies.[33] However, the SPD results should be seen as an indicator of relative rather than absolute change.[34] Archaeologists selectively radiocarbon date certain chronological periods, leading at times to exaggerations of inferred demographic fluctuations. Parallel developments can be seen in the synthesis of regional site surveys into larger, supra-regional datasets,[35] and especially the testing of new methods to process these datasets for comparison with environmental records. One example is the aoristic approach that compensates for the sometimes very unequal lengths of archaeological periods and thus helps to offset some of the chronological staticness of regional survey data.[36] In parallel, different varieties of kernel density estimations have been developed that convert point pattern data to land use areas that are better equipped to estimate the overall spatial extent of land use and the environmental specifics of any fluctuations therein.[37]

Notable among the method keywords are also the modelling approaches, predominantly linked to land use. These are connected to agricultural productivity and water availability, modelling runoff, irrigation or crop yields,[38] and to ways of assessing the content and spatial extent of land use and potential climate change impacts.[39] Comprehensive Earth System Models (ESM) have made it possible to simulate the climate system and the interactions and feedbacks among the climate subsystems, e.g. physical, chemical and biological processes, in order to improve our understanding of the past, current and future climate system. Recent efforts among archaeologists aim towards quantification of ancient land use in a way that can be used to improve the understanding of anthropogenic land cover change, specifically assumptions regarding per capita land use currently used in global-scale ESM models.[40] While these efforts are predominantly directed towards the needs of developing data and models to predict future scenarios, modelled climate information is also increasingly used to understand past human-environment interactions in the Mediterranean world. The usefulness of modelled climate sequences (ESMs as well as lower-resolution and hence less computationally demanding Global Circulation Models, GCMs) to investigate and understand societal change have been demonstrated by ongoing work in Anatolia, Mesopotamia and France.[41]

TOPIC

The largest category of keywords (n=630, 41%) was divided into nine general subcategories: Climate, Environment, Hydrology and soil, Land cover, Landscape, Land use, Dynamics, Theory and concepts, and Archaeology and history (*Fig. 3*, and *Appendix*). Due to the great number and variety of topics, keywords in these subcategories were further divided into additional thematic keyword-based groups (called “thematic groups”) based on the materials used and the aspect of human-environment dynamics primarily indicated. Space does not allow a full consideration of the details of these themes or of the results of the individual studies. The following overview will therefore focus on the major themes, each exemplified by references to relevant studies, while a more detailed view of some of the studies will be the given in the second part of this article. The brief

31 Izdebski *et al.* 2016, 15–16; Servera-Vives *et al.* 2018, 11.

32 Izdebski *et al.* 2016, 15; e.g. Bevan *et al.* 2019 and the articles included in the 2019 *Holocene* special issue stemming from the *Changing the Face of the Mediterranean* project.

33 Lillios *et al.* 2016; Bevan *et al.* 2019; Roberts *et al.* 2019a; Palmisano *et al.* 2017. See also Palmisano *et al.* 2021a; Parkinson *et al.* 2021.

34 Weiberg *et al.* 2019a, 755; Palmisano *et al.* 2021a, 5–8.

35 What constitutes a “region” is something of a grey area and can differ vastly between disciplines. A region is generally smaller in archaeology (a survey region, or a culturally defined area) than in palaeoclimatology, for which an archaeological region more likely would be considered a part within a larger region. Notably, “region” is only one of several concepts that need special attention in interdisciplinary collaborations; others include for instance long-term/short-term and other chronological terminologies, see e.g. Lane 2015; Izdebski *et al*. 2016.

36 Palmisano *et al.* 2017; Weiberg *et al.* 2019a; Woodbridge *et al.* 2019.

37 Bonnier & Finné 2020; Lawrence *et al.* 2021; Weiberg *et al.* 2021.

38 Meister *et al.* 2018; Bruins *et al.* 2019; Contreras *et al.* 2019; Kaptijn & Ertsen 2019; Whitford 2019; Van Loo & Verstraeten 2021; Arıkan *et al.* 2016.

39 Knitter *et al.* 2019; Bernigaud *et al.* 2021; Vidal-Cordasco & Nuevo-López 2021.

40 Weiberg *et al.* 2019b; Morrison *et al.* 2021. See also the *Past Global Changes* (PAGES) LandCover6k project: https://pastglobalchanges.org/science/wg/landcover6k/intro.

41 Arıkan & Yıldırım 2018; Gauthier 2016; Contreras *et al.* 2018b; see also Cookson *et al.* 2019.

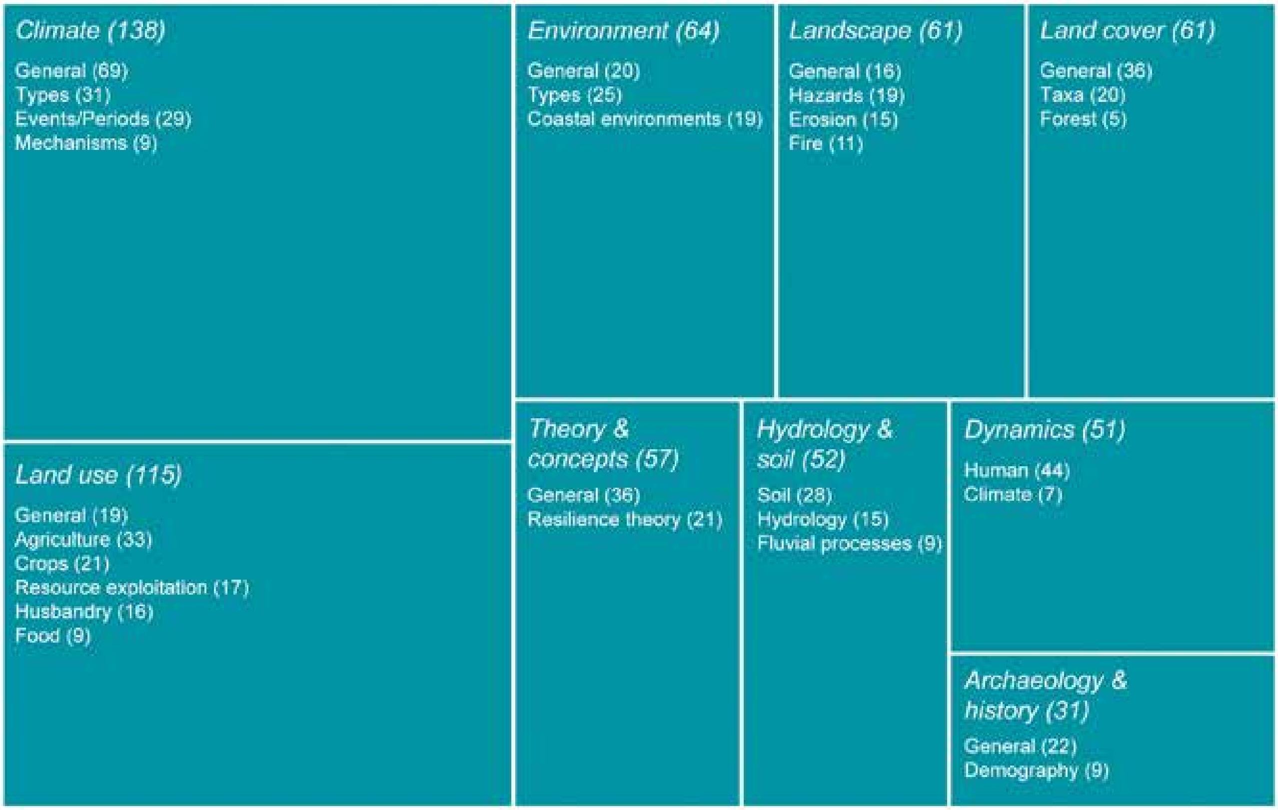

Fig. 3. The relative importance of the groups of keywords in the Topic category illustrated as a tree map, with the size of each box indicating the number of keywords assigned to each specific subcategory and further divided into thematic groups. Absolute number of keywords are given for each subcategory as a whole as well as for the thematic groups. See also Appendix*. Illustration by M. Finné and E. Weiberg.*

overview below provides a smorgasbord of avenues for further study based on the readers' interests. Overall, the themes highlight the special climatic and environmental conditions in the Mediterranean, as well as the challenges these bring. Notably, however, many of the themes are important for our understanding of human-environment dynamics in the past and for understanding how changes in the past may provide insights for the future of these and similar environments, and resonate very well with the grand challenges and priority research questions listed for archaeology, historical ecology and palaeoecology.

As a reflection of the search strings used, *Climate* (n=138) is the single largest subcategory, dominated by general keywords such as climate and climate change. Specific keywords in this subcategory signify the continued interest in chronological periods allegedly connected to rapid climate change (RCC) ("events") and their detrimental effects on human societies, most notably the rapid climate events at 4.2 ka BP (i.e. 2250 BC).[42] A clear focus on hydroclimate, primarily controlled by precipitation and evapotranspiration, is evident, reflecting the importance of water and water availability in the relatively dry Mediterranean. This stands in contrast to northern Europe, for example, where temperature is a more decisive factor for human activities and specifically for agriculture, and studies favouring temperature are also more prominent as shown by a recent research overview of climate and society in later European history.[43]

As with climate, many of the keywords denoting *Environment* (n=64) are general in nature, signifying the interest in reconstructing palaeoenvironments, while other keywords describe types of environments or places that lack specific geographical markers, such as "dune", "karstic cave" and "wetland". A special interest can be discerned for the dynamic coastal environments that can be found around the Mediterranean Sea and their evolution across time, including investigations of sea

[42] Lillios *et al.* 2016; Blanco-González *et al.* 2018; Jalali *et al.* 2019; Jalali & Sicre 2019; Ocakoğlu *et al.* 2019; Whitford 2019; Schirrmacher *et al.* 2020; Lawrence *et al.* 2021.

[43] Ljungqvist *et al.* 2021, 4.

level and sea-level fluctuations,[44] with clear links to projected sea-level rise linked to the warming of the Mediterranean.[45]

The subcategory *Hydrology and soil* (n=52) comprises a set of keywords that relates to hydrology and hydrological processes, and describes soils, soil types and processes affecting and altering soils, as well as a number of fluvial processes and landforms. Many of the keywords related specifically to soils are linked to agricultural practices highlighting an interest in understanding how soil and soil quality affects agricultural potential of an area.[46] A related set of keywords signals a special interest in water availability and links to projects on agricultural terrace systems in the Mediterranean.[47] Overall, this is a rather technical subcategory with a strong natural science emphasis but with important links to agriculture and forms of human land use.

Various aspects of vegetation dynamics, including the evolution of natural vegetation, and aspects of Mediterranean land cover beyond agricultural areas are captured in the *Land cover* (n=61) subcategory. Included in this subcategory are keywords that relate to vegetation on a general level while another group of keywords is more botanic/systematic and contains plant types, families and species. The latter thematic group includes species and taxa that primarily represent the Mediterranean-type forest and woodlands, with studies focusing specifically on pine, fir, beech or oak.[48] Overall, most keywords in the subcategory come from pollen-based studies that take long-term perspectives on vegetation change and its causes, with additional links to anthracology and the exploitation of woodland resources.[49]

The keywords in the subcategory *Landscape* (n=61) are in different ways linked to landscapes and landscape types but also to processes that occur at landscape level and are important agents in shaping the landscape. A general focus on landscapes per se are complemented by studies of fire, erosion and other types of environmental hazards. While erosion has been a core topic among human-environment interaction studies for a long time,[50] the interest in fire and hazard studies seems to have increased more recently. Studies on fire regimes cover the full span of the Mediterranean, although with an emphasis on the central and western parts, and explore the impact of fires—anthropogenically induced and/or natural—on the vegetation cover.[51] Many of the studies relating to fire provide a clear view towards current and future woodland management by raising issues of biodiversity and wild fire control.[52] A small group of keywords relate specifically to flood hazards,[53] while other keywords are directly linked to tectonic hazards (i.e. earthquakes, tsunamis and volcanoes),[54] highlighting how tectonically active parts of the Mediterranean are, especially the central and the north-eastern parts.

The second largest subcategory relates to *Land use* (n=115), which beyond general mentions of "land use" showcases core economic components of ancient Mediterranean societies, namely—in order of quantity—agriculture, crops, husbandry, resource exploitation, and food (*Fig. 3* and *Appendix*). Most commonly the keywords are of a general kind, defining the studies as relevant to agriculture/farming in general terms, while others link to husbandry in a similarly general way. The thematic group incorporating crops, however, clearly reflects the three traditional staples in the Mediterranean: grain, olive oil, and wine (the Mediterranean triad), of which olive is the most prevalent.[55] Perspectives of resource exploitation are dominated by wood management for fuel and water management/harvesting.[56] A final and smaller group refers to issues of food production and storage with considerations of the sustainability of food production.[57] With food security being a key topic in current sustainability debates, the studies of this topic within archaeology is likely to increase.[58]

The subcategory *Dynamics* (n=51) captures keywords that define human-environment-climate dialectics. The most common unique keyword here is "human impacts" (the third most frequent keyword used overall, a position shared with the chronological keyword "Bronze Age") and covers a broad range of studies that are mostly multi-proxy with a focus on vegetation histories and environmental reconstructions studying the strength and variety of the impact of human socie-

44 Geraga *et al.* 2017; Dean *et al.* 2019; Gzam *et al.* 2019; Ronen & Almagor 2021.
45 Vacchi *et al.* 2021.
46 Braje *et al.* 2017; Contreras *et al.* 2018b; French *et al.* 2018; Van Loo & Verstraeten 2021.
47 Stavi *et al.* 2018; Bruins *et al.* 2019; Moreno-de-las-Heras *et al.* 2019; van Bommel *et al.* 2021; see also Brown *et al.* 2020.
48 Beffa *et al.* 2016; Aranbarri *et al.* 2020; Tinner *et al.* 2016; Morales-Molino *et al.* 2021; Moser *et al.* 2017.
49 Deckers 2016; Picornell-Gelabert *et al.* 2021.
50 Bintliff 2002; Butzer 2005.
51 López-Sáez *et al.* 2018; Marriner *et al.* 2019; Mercuri *et al.* 2019b; Norström *et al.* 2021.
52 Tinner *et al.* 2016; Connor *et al.* 2019; Lestienne *et al.* 2019; Morales-Molino *et al.* 2021; Pedrotta *et al.* 2021.
53 Liritzis *et al.* 2019; Rapuc *et al.* 2019; Bini *et al.* 2020; Pennos *et al.* 2021. Hazards denote events that may cause adverse consequences for humans and societies and objects and things of value to them.
54 Katrantsiotis *et al.* 2016; Liritzis *et al.* 2019; Werner *et al.* 2019; Zanchetta *et al.* 2019.
55 D'Auria *et al.* 2017; Finkelstein & Langgut 2018; Langgut *et al.* 2019 (overview article); Mercuri *et al.* 2019b; Caracuta 2020; Galili *et al.* 2021; Jouffroy-Bapicot *et al.* 2021.
56 Fuel: Bouchaud *et al.* 2017; D'Auria *et al.* 2017; Janssen *et al.* 2017; Marinova & Ntinou 2018; Picornell-Gelabert *et al.* 2021. Water: Pustovoytov & Riehl 2016; Enrich & Mejías 2017; Junge *et al.* 2018; Meister *et al.* 2018; Bruins *et al.* 2019; Kaptijn & Ertsen 2019.
57 Meister *et al.* 2018; Kaniewski *et al.* 2019; Dibble & Finné 2021; Gaastra *et al.* 2021; Jazwa & Jazwa 2021; Weiberg *et al.* 2021.
58 Cf. Nelson *et al.* 2016

ties on their environment. While most keywords put humans in primary focus ("human impact", "human-environment interaction"),[59] a small group favours climate ("climate impact", "climate adaptation"),[60] which leaves humans in a more responsive position vis-à-vis the environment.

The keywords in the subcategory *Theory and concepts* (n=57) also highlight human-environment-climate dialectics and specifically how humans relate, react and adapt to their environment and any changes therein. It is a very diverse set of keywords and the only grouping that can be discerned is made up of keywords related to the framework of resilience theory, such as the concept "resilience" itself,[61] which together with keywords such as "sustainability", "adaptation", "adaptive cycle", "vulnerability" and "mitigation" signify an interest in current sustainability debates. In conjunction with the continued interest in periods of rapid climate change highlighted above, this group of keywords also signifies an interest in nuancing our understanding of the linkages between environmental and societal change.

Finally, keywords related to *Archaeology and history* (n=31) constitute the smallest subcategory, which perhaps can be seen as a reflection of the lack of significant archaeological proxies for studies of human-environment dynamics beyond those signifying demography in some sense, based on settlement patterns and radiocarbon SPD.[62] Such demographic indicators make up the only group of keywords that stands out in this subcategory and, as already noted, this is also a topic that has seen considerable methodological development recently.

SUMMARY: THE SIGNIFICANCE OF KEYWORDS

The nine subcategories within the Topic category provide insight into the main themes of present-day research on human-environment dynamics in past Mediterranean societies. Moreover, the keywords of many articles are spread across these subcategories, signifying the interdisciplinary nature of this research environment unified by an interest in human-environment dynamics. Together with the keywords of the other categories (Geography, Discipline, Chronology, Method, Archive and Proxy), they provide the outlines of a research environment that is continuously developing in parallel with new techniques and new lines of enquiry. Considerations of author affiliation and the composition of author groups support the diversity of the group of scholars, both in terms of numbers of authors as well as regarding disciplinary and national affiliation.

Moreover, a survey based on keywords allows some focus on the motivations behind the choices of keywords. There are likely to be differences in how much thought goes into the choice of keywords, whether they are selected quickly and by necessity or after more thorough consideration and for a specific purpose. The purpose may be to define the study thematically, geographically and chronologically. It could also be to highlight the source material used and/or specifically to spark the interest of an intended readership or link to current trends. The choice to include "archaeology" among the keywords, for example, marks a discipline but is also closely tied to a specific type of source material. The keyword can be used to set the study apart from studies using historical sources, or it can be a way of highlighting the use of archaeological source material within a research field commonly more directed towards sources beyond the humanities and social sciences. In the latter case it could be to emphasize that the study includes direct evidence from the human side of human-environment dynamics. Such details are difficult to pick out from the keywords themselves, but allow room for future and more detailed studies of the links between keywords, affiliations, citations and the actual content of the articles.[63] Based on the present review, it can nevertheless be concluded that the keywords are generally rather technical in nature, providing information on the ingoing datasets, the source material and the methods, and sometimes the theoretical perspectives, rather than the results of the studies themselves.

Part two: understanding change across time and space

In this second part of the article, we range beyond the keywords and go into some further detail regarding the results in some of the 280 articles. The purpose is to discuss some overarching considerations relevant to them all, specifically issues of time and scale and their relevance for our understanding of causality within human-environment dynamics. These issues will provide insights into the challenges as well as the potentials of studying human-environment dynamics, and the key importance of interdisciplinary efforts. Notably, there are calls for action among the selected articles, and others published during the last five years, that highlight the need for such interdisciplinary research, showing that human-environment dynamics is a vibrant field of study that remains under scru-

59 Contreras *et al.* 2018a; López-Sáez *et al.* 2018; Marinova & Ntinou 2018; Marriner *et al.* 2019; Mercuri *et al.* 2019b.
60 Marston & Branting 2016; Contreras *et al.* 2019.
61 Flohr *et al.* 2016; Allcock 2017; Primavera *et al*. 2017; Weiberg & Finné 2018; Kaptijn & Ertsen 2019; Azuara *et al.* 2020; Weinelt *et al.* 2021.
62 Drake *et al.* 2017; Berger *et al.* 2019; Palmisano *et al.* 2019; Weiberg *et al.* 2019a.

63 E.g. Pesta *et al.* 2018.

tiny in terms of best practice, ways forward and the remaining challenges.[64] A special emphasis is put on the need for reliable communication across disciplines, between the humanities and natural sciences,[65] but also between more closely related fields of study, such as between palaeoecology and ecology.[66] Only through such joint attempts are we likely to come close to disentangling and understanding, for example, the variable effects of natural and anthropogenic changes on the environment or the intricacies of human-climate relationships. Such collaborative efforts entail hard work and a mutual understanding of the potential, but importantly also the challenges and uncertainties of each of the discipline-specific datasets employed in interdisciplinary studies in order to avoid simplistic explanations.[67] The methods for combining discipline-specific datasets need also to be carefully considered and the choices made transparent, not least in terms of chronological comparability and means for identifying and critically assessing causal relationships between processes and events.[68] In the same vein, we find a concern for more theoretical and interpretative issues associated with questions of time, scale and complexity.[69] These strongly interlinked issues are quintessential to the study of human-environment dynamics and for studies of past human societies overall.

As a reflection of the prominence of "climate" in the search strings used, the discussion below focuses on issues of climate and climate change relative to human societies, which will inevitably also include issues of more environmental concern. Climate conditions and climate change can have far-reaching effects and impacts on many variable aspects of human societies. These effects can be seen as variables connected to climate change itself: there are direct physical effects (first-order impacts) that may affect the quantity and quality of agricultural production, for example, which in turn can influence human livelihoods and the socio-economic system (second-order impacts), which can have considerable social and demographic implications (third-order impacts), and trigger cultural responses (fourth-order impacts), and all along this trajectory, any change that occurs can initiate adaptation strategies and mitigation measures to deal with the effects of change.[70] Generally, the climate of the Mediterranean area is characterized by dry summers and mild wet winters modulated by altitude, creating a number of climate and vegetation zones.[71] Precipitation displays strong interannual variability across the region, and there is a general decline in the amount of rainfall and in the length of the wet season towards the east. Due to high interannual variability and rainfall constraints, climate is often seen as a limiting factor and as a key parameter for agriculture, fresh water supply as well as for vegetation change.[72] In academia, due to these limiting factors, the formation, growth and durability of societies during the Holocene has frequently been linked to climate and to climate change, correlations which have also been challenged.[73]

TIME: LONG-TERM VERSUS SHORT-TERM PERSPECTIVES

The temporal scope of a study will affect the level of contextual detail that can be incorporated and will thereby also influence the questions that can be asked and answered. A wider temporal scope will inevitably require higher degrees of generalization.[74] Evaluation of long-term processes serves nevertheless the key purpose of highlighting general patterns and completed trajectories of change that are more easily compared to other case-studies.[75] Short-term perspectives allow more room for details but run the risk of overlooking the effects of slower working processes of relevance for a specific outcome.

Looking from the perspective of the entire Holocene, the scale of human presence and the impact of this presence on the environment has increased exponentially across the millennia.[76] Notably, the general population growth runs in parallel with a general and continuous aridification trend that is especially noticeable in the southern and eastern Mediterranean.[77] On this level, it must be concluded that ancient societies developed despite the deterioration of climatic conditions and, if anything, climate served as "a prompt and stimulus to innovation rather than retarding societal development".[78] This seems especially true from the beginning of the Bronze Age onwards, when several studies note a decoupling of climate and demographic trends.[79] There is also evidence for simultaneous decoupling of climate and vegetation, with changes

[64] Among the selected articles: Izdebski *et al.* 2016; Marignani *et al.* 2017; Post 2017.
[65] Izdebski *et al.* 2016.
[66] Marignani *et al.* 2017.
[67] Izdebski *et al.* 2016, 19; Marignani *et al.* 2017, 904; Degroot *et al.* 2021, 542.
[68] Contreras 2017, 8–10; Degroot *et al.* 2021, 541–542; Ljungqvist *et al.* 2021, 15.
[69] Holmgren *et al.* 2016, 3–4; Knapp & Manning 2016; Degroot *et al.* 2021, 542; Ljungqvist *et al.* 2021, 16.
[70] Luterbacher & Pfister 2015, 248, fig. 2; Ljungqvist *et al.* 2021, 4, fig. 2.
[71] Izdebski *et al.* 2016, 6, fig. 2.
[72] García-Ruiz *et al.* 2011.
[73] E.g. Middleton 2012; Jung & Weninger 2015; Knapp & Manning 2016; Haldon *et al.* 2020.
[74] Lane 2015, 15–16; Izdebski *et al.* 2016, 16.
[75] Lawrence *et al.* 2016, 10–11; Allcock 2017, 79.
[76] Roberts *et al.* 2019a.
[77] Finné *et al.* 2019, 854, fig. 4.
[78] Roberts *et al.* 2019a, 931.
[79] Lawrence *et al.* 2016, 2; Palmisano *et al.* 2021b, 22–23.

in land cover being increasingly human-induced from the Bronze Age onwards.[80]

Scaling down to a centennial scale, settlement and population cycles can be noted in most Mediterranean regions, based on the number of identified sites in archaeological surveys and in the fluctuations in radiocarbon SPD.[81] These fluctuations can be chronologically aligned to similarly timed oscillations in climate. Focus remains here on periods of negative climate change (periods of aridity) and their effect on societies; but evidence of the positive effects of wetter climate conditions is also mounting and even evidence of societal expansion despite what is generally seen as unfavourable (i.e. drier) climate conditions on centennial timescales. Studies considering long-term societal development relative to short-term climate change come from across the Mediterranean, most notably studies of the periods leading up to and beyond the 4.2 ka BP (2250 BC) and 3.2 ka BP (1250 BC) climate events. Studies of the vegetation history of the Terramare civilization (1550–1170 BC) confirm the coincidence between arid conditions and the collapse of this civilization. Aridity may have impeded successful management of natural resources and thereby contributed to the societal breakdown, but it also noted that climate could have been one of the main enabling factors for the initial settlement expansion of the Terramare civilization.[82] Similar arguments have been forwarded for Late Bronze Age Greece and the Chalcolithic and Early Bronze Age Fertile Crescent, arguing that periods with above-average rainfall contributed to increased productive capacity and supported settlement expansion, as noted by increased site numbers and arguably population numbers, and resulted in an economic boom.[83] Notably, in both cases, the largest-scale expansion and contraction of settlements occurred in marginal and arguably less fertile areas. The expansion into marginal areas clearly added to the overall vulnerability. In these two cases, as well as in the case of the Terramare civilization, climate change was a factor both in the growth and decline of societies, by facilitating expansion that ultimately led to an unsustainable socio-economic system. Similarly, the Copper and Bronze Ages on the Iberian peninsula have been extensively investigated in relation to demographic cycles and climate change, in terms of long-term change (*c.* 6000–3000 BP/4050–1050 BC) relative to the 4.2 ka climate event and the Copper to Bronze Age transition (*c.* 2400–1900 BC).[84] By contrast to the previous examples, it is concluded in one article that several occupation phases, and especially the El Argar culture (2200–1400 BC) "all partially occurred under preponderantly unfavourable climate constraints."[85] The authors emphasize the high resilience of these societies enabled by a number of possible adaptive strategies pertaining to the agro-economic system. They also suggest that the progressive erosion of cultural developments and of the efficacy of the adaptive strategies led to socio-environmental "collapse", especially when reinforced by aggravated climate circumstances and demographic stress.[86] Significantly, the zenith of the El Argar culture is connected to signs of rapid deforestation and changes in the herb community observed in palaeoecological sources, signalling high human pressure and the degradation of natural resources over time.[87]

SCALE: GEOGRAPHICAL AND CHRONOLOGICAL RESOLUTION

When we now turn to a consideration of scales, it should be noted that temporal and spatial scale do not always go hand in hand. Most notably, vegetation histories and landscape reconstructions generally provide very local data but outline changes in the local environment developing over millennia. An appreciation of chronological resolution is thereby paramount for integration of the results with archaeological and historical information, and other datasets that may be equally local but chronologically more (and sometimes less) highly resolved.[88] From a palaeoclimatological point of view it is primarily at the level of larger regions within the Mediterranean (e.g. the Aegean) that we can detect coherent trends of climate change,[89] and climate model output tends to be similar and often even more large-scale. However, this scale contrasts with the intrinsically local scale of human activities as well as of much archaeological and historical data on which we base our understanding of past human societies. The imbalance between the local human histories and the regional to global character of the climate data presents a challenge. Consequently, there have been recent calls for the need to downscale climate model data.[90] In a local case-study from Provence (south-east France), Contreras *et al*. use low-resolution climate data from a GCM to generate data at the landscape scale by using statistical downscal-

80 Jaouadi *et al.* 2016, 1349–1350; Miebach *et al.* 2016, 588–589; Glais *et al.* 2017, 418–419; Mercuri *et al.* 2019a.
81 Allcock 2017; Bevan *et al.* 2019, and all case-studies in that special issue; Lawrence *et al.* 2021; Weinelt *et al.* 2021.
82 Cremaschi *et al.* 2016, 154, 168–170.
83 Weiberg & Finné 2018, 593–597; Lawrence *et al.* 2021, 14–16; Weiberg *et al.* 2021, 9–10.
84 Lillios *et al.* 2016; Blanco-González *et al.* 2018; Schirrmacher *et al.* 2020; Weinelt *et al.* 2021.
85 Weinelt *et al.* 2021, 13–14.
86 Weinelt *et al.* 2021, 14.
87 Azuara *et al.* 2020, 9.
88 Izdebski *et al.* 2016; Knapp & Manning 2016, see also Lane 2015; Finné & Weiberg 2018.
89 Finné *et al.* 2019; see also Roberts *et al.* 2011.
90 Contreras *et al.* 2018a.

ing.[91] From the downscaled results they explore how modelled precipitation amounts and temperature may have affected the distribution of settlements in the area over time, showing the potential of downscaling climate parameters. By capturing both spatial variability and interannual variation in climatic factors, the authors argue that it is possible to build better and more complex scenarios regarding how agriculture was affected and what repercussions climate change had for local societies.[92] Ongoing efforts to increase the number and geographical distribution of climate proxy data is another factor that can contribute to better understanding of the regional character of climate change across the Mediterranean (i.e. similarities and differences) but also at the smaller scale. With a denser network of climate records, an opportunity opens up for more locally based comparisons with archaeological and historical data.[93] Some of the highest-resolved and chronologically best constrained climate proxy data come from cave speleothems (stalagmites), although these archives are still relatively few.[94] The number of sediment archives is more substantial and they provide important palaeoenvironmental information.[95] More importantly, they offer the opportunity for multi-proxy analyses that can reveal natural as well as anthropogenically induced changes using proxies from coeval levels. Adding to this are new proxies from wetland and lacustrine sediments, such as highly resolved geochemical data,[96] and stable hydrogen isotopes in leaf wax n-alkanes,[97] both of which record climate-related conditions such as moisture balance, temperature and precipitation. Efforts are also initiated to add new types of climate archives for locally based climate studies utilizing, for instance, shells from land snails to investigate the climate at the very smallest spatial scale.[98] To reach the full potential of the variety of climate archives and proxies, there are still issues to be resolved, specifically related to regional variability and the synchronous differences between nearby climate archives, taking into account varying forcing factors, site-specific responses and chronological precision.[99]

The local environment in a valley or on an island was probably most important for humans and human activities, but comparisons between regions and contexts allow more generalized understandings of the variable societal trajectories, the range of decisions made, as well as the relevance of climate and other environmental forcing factors. Integrated studies of archaeology and climate have shown, for example, that it is possible to outline disparities in settlement patterns between regions that may indicate variable local responses to regional climate change due to environmental and/or socio-economic circumstances.[100] By scaling up local (and regional) datasets to more general estimates of land use (based on historical sources, archaeology, archaeobotany, zooarchaeology, etc.), it is possible to begin to outline changes in land use across time and space.[101] The spatial requirements of specific livelihoods (the land footprint) can then be estimated and used to quantify the scale of human impact on the environment and thereby the potential vulnerability of human societies to climate change and other external forcing factors. Of great relevance for current-day state of affairs, studies have stressed the considerable impact of diet on our overall footprint,[102] the likely dependency of large (Mycenaean) settlements on non-local food supplies,[103] as well as the considerable impact of climate conditions (due to changing yields) on the overall land footprint.[104] A common denominator is the overriding importance of population levels for the overall human imprint on the landscape, raising the need for further estimates of population densities at both local and regional levels for accurate assessments of human-environment dynamics. This need is currently met by refining available demographic proxies, but we take this opportunity to encourage archaeologists to more frequently attempt to quantify (in absolute numbers) the spatial scale of settlements and/or population numbers, even if the data are less than satisfactory.[105] Many land-use estimates currently used in global-scale models rely on quantifications that are weakly or not at all based on archaeological evidence.[106] Even with broad estimates—of land use as well as population—archaeologists can potentially make important contributions.

When upscaling or downscaling, or when comparing between scales and between disciplines, however, the comparability of the ingoing datasets must be assessed. For the best fit between research questions and data and for the best

[91] Contreras *et al.* 2018b; 2019.
[92] Contreras *et al.* 2018b, 20–21.
[93] Izdebski *et al.* 2016, 18; Degroot *et al.* 2021, 541–542.
[94] Finné *et al.* 2019, table 1, 850–851.
[95] These can be chronologically very well-constrained in rare cases of annually laminated sediments (e.g. Lake Nar: Allcock 2017; Roberts *et al.* 2019b, with references therein).
[96] Allcock 2017; Seguin *et al.* 2019; 2020a.
[97] Katrantsiotis *et al.* 2018; Norström *et al.* 2018.
[98] Lewis *et al.* 2017; Yanes & Fernández-Lopez-de-Pablo 2017; Prendergast *et al.* 2018.
[99] Seguin *et al.* 2020b, 175–177.
[100] Bonnier & Finné 2020; Lawrence *et al.* 2021; Weinelt *et al.* 2021.
[101] Morrison *et al.* 2021; see also Stephens *et al.* 2019. Both studies stem from LandCover6k working group within the *Past Global Changes* (PAGES) project: https://pastglobalchanges.org/science/wg/landcover6k/intro.
[102] Hughes *et al.* 2018, 11–12.
[103] Knitter *et al.* 2019, 7–9.
[104] Hughes *et al.* 2018, 12–13; Knitter *et al.* 2019, 7–9.
[105] The propensity for quantified estimates does vary between contexts, partly as a reflection of the natural visibility of settlements and their extension (e.g. in the flat landscape of Mesopotamia: Lawrence *et al.* 2016) and/or on the scale of archaeological activity in any one location (e.g. the urban survey around the palace of Knossos on Crete: Whitelaw 2019).
[106] Weiberg *et al.* 2019b, 2–3; Morrison *et al.* 2021, 3–4.

complementary datasets across disciplines, especially when taking into account the heterogeneous nature of the Mediterranean climate and environments both in the present and in the past, palaeoenvironmental information and archaeological/historical data should come from the same location or at least nearby. Luckily, with the increasing availability of climate proxies across all regions of the Mediterranean, spatially congruent studies are an achievable goal, as the reliance on distantly located palaeoclimate data is reduced in favour of more locally based datasets. In terms of chronology, the key is to let the lowest resolution data guide the overall resolution of the study. On a regional scale, this may mean coarsening the resolution of the climate data to match the relative chronology of the archaeological survey data. Studies of the time from the Middle Bronze Age to the Roman period in the Peloponnese have shown coarsening to be a very effective way to identify coeval cyclicity of climate and societal development. In this case, stable isotope values interpreted to show drier (wetter) conditions in each archaeological period were summed and considered to indicate the overall climate during that specific period.[107] Given that archaeologists generally cannot judge the contemporaneity of sites assigned to each period, an aggregate of sites is thereby compared to an aggregate of climate indicators, and what is lost in climate detail (short-term events) is gained in terms of comparability between the datasets.[108]

CAUSATION: HUMAN AND CLIMATIC DRIVERS OF CHANGE

The question of anthropogenic versus climatic impacts is a theme that brings to the fore issues of both time, space and resolution of records, and transcends several of the topics highlighted among the selected articles. It is also a theme that is targeted head-on by several of the studies discussed here, showing that the complex question of causation is far from resolved despite considerable research. Something that is increasingly clear, however, is that the answer more often than not lies in the context-specific details. A multiplicity of parallel data series as well as careful considerations of the comparability between them is crucial to move from correlation to causation. In the *Holocene* special issue resulting from the *Changing the Face of the Mediterranean* project, for example, multiple datasets were binned into 200-year time windows.[109] At this level of comparability, it is possible to statistically test the correspondences and potentially the causal linkages between human, climate and environmental factors of change over millennial and centennial timescales.[110]

Many of the studies, across the Mediterranean, make evident that anthropogenic impacts are strong. The drivers of soil erosion, for example, have been widely debated for several decades, i.e. whether the impact of climate or anthropogenic activities dominates or if it is a combination of the two factors.[111] A 2019 review concluded that there is an overall trend of increased sediment dynamics during the last four millennia (i.e. from the Bronze Age), developing alongside an aridification trend *and* overall population growth. These general trends are complemented by notable local and regional-scale oscillations in the intensity of sediment flux for which few supra-regional correlations can be found.[112] A study based on a very highly resolved varved sediment record from Lake Nar in central Anatolia shows that although in some time windows, high erosion rates concur with arid climate conditions, climate factors alone are not enough to explain erosion and that there is a chronological match between peaks in the total influx of sediments into the lake and indicators of human activity (based on archaeological and/or pollen indicators).[113] Both the 2019 review and the Anatolian case-study assign climate change an amplifying role, acting as pacemaker for erosion events, but that climate change alone, in the absence of human impact, is unlikely to result in increased erosion.[114]

The strength of the human impact is clear also when it comes to the fluctuation of tree cover across time, but the drivers of vegetation change are complex, with climate and human effects interacting. Deforestation constitutes a significant component of the anthropogenic activities influencing erosion, and the statistical evaluation of linkages between demographic proxies and forest extent (as indicated by mean percentage of arboreal pollen [AP]) in 200-year time windows resulted in a significant correlation across time in many of the studied regions, but also that the degree and the sign of the correlation coefficient varied across the Mediterranean.[115] The strongest negative correlation was found in the originally most-wooded areas of the western and central Mediterranean, where mean AP percentages were >65% prior to major human impacts (prior to *c.* 2000 BC).[116] In regions with medium-extent forest cover (30–60% AP), no significant correlation was found and in some regions with <30% AP there was even a positive correlation, signalling that human activities led to

107 Bonnier & Finné 2020, 1489–1491; Weiberg *et al.* 2021, 4–5.
108 Weiberg *et al.* 2021, 9.
109 Roberts *et al.* 2019a, 924–925.
110 Roberts *et al.* 2019a, 930–935.
111 Bintliff 2002; Butzer 2005.
112 Walsh *et al.* 2019, 876–879.
113 Roberts *et al.* 2019b, 44–46.
114 Walsh *et al.* 2019, 879; Roberts *et al.* 2019b, 46.
115 Roberts *et al.* 2019a, 930–931.
116 See also Berger *et al.* 2019; Fyfe *et al.* 2019.

an overall increase in woodlands.[117] The variations in original tree cover, however, is of course predicated by the climate and vegetation zones of each specific region, and climate effects on forest cover cannot be disregarded. In a study exploring the effect of the 4.2 ka BP climate event on AP in the central Mediterranean, evidence supports an increase and decrease of forest due *primarily* to climate change and only secondarily to human activity (by way of amplification). These effects, however, differed with latitude, with no significant vegetation change noted for locales north of 43° N, but with a marked forest decline south of 43° N indicating a sensitivity of forest communities to arid events, especially south of 39° N (including the southernmost part of mainland Italy and Sicily).[118] A number of Iberian case-studies tie into the same human-climate conundrum relative to the drivers of vegetation change. In north-east Spain, a review of several pollen profiles, with specific attention to Aleppo pine (*Pinus halepensis*), seems to show that vegetation changes were driven more by climate than human factors (e.g. by use of fire for clearing purposes), at least in earlier periods. Here, moister conditions during the Neolithic (7500–3400 BP, or 5550–1450 BC) led to a considerable reduction of the Aleppo pine that was better adapted to the more arid conditions in the preceding and succeeding periods during which this pine species was more prevalent in both palynological and archaeobotanical records.[119] This conclusion stands in some contrast to a study of fire regimes spanning the whole of the Iberian Peninsula that favours the interpretation that the opening of the woodlands during the Neolithic was due to increased anthropogenic use of fire for the management of agricultural lands.[120]

Adding even further to the complexity of understanding human-environment dynamics is the fact that ingoing parameters—climate, environment and human societies—are decidedly complex entities in themselves. As we have seen, the local climate and vegetation zone must be taken into account. If we now turn from a focus on vegetation to the effects of climate change on human societies, there are a number of climate parameters that could be taken into account that likely impacted human societies in different ways. Most studies deal with relative changes in hydroclimate, i.e. periods of wetter or drier conditions, which is the most common parameter in the climate records of the Mediterranean,[121] but a growing number of studies also attempt to incorporate changes in temperature as well as the timing and amplitude of any changes. Schirrmacher *et al*. provide a detailed analysis of a large variety of climate proxies across the Iberian peninsula, discussing trends of seasonality and the impact of superimposing trends of both temperature and precipitation in 200-year time windows (3250–1450 BC), with important considerations also of the quality of the ingoing datasets.[122] Another consideration is the stability of the climate over the short-term (years and decades), with the assumption that increased interannual volatility affects the predictability and therefore the success rate of any social strategies to deal with "normal" variability. Stability in climate, on the other hand, regardless of the exact climate conditions (whether "good" or "bad"), allows societies time to establish productive (risk) management strategies.[123]

These adaptive measures are studied by several of the articles reviewed here. Many articles link to the framework of resilience theory and social-ecological systems (SES), in a few instances using the conceptualization of the adaptive cycle,[124] but more commonly forwarding the ideas of resilience and/or vulnerability in more general terms. In most cases, the level of resilience is gathered from an appreciation of the level of social/economic/environmental/political/demographic change in the face of disturbances, while in other cases the focus is rather on resilience as a measure of societies' capacity to adapt to changing circumstances and the content of these adaptive strategies. In the first instance, studies suggest a pattern of no-change in the face of climate change, such as the resilience of certain types of vegetation,[125] or the lack of any significant pattern of demographic change.[126] In the second instance, studies highlight, for example, changes in agricultural strategies based on specific environmental conditions and/or following climate change,[127] the benefits of irrigation and rainwater harvesting for cultivation in arid climates and in response to arid events,[128] or the sail as a technology of resilience for small-world connectivity in troubled times.[129] Several studies highlight that the level of resilience—or of adaptive capacity—was dependent on a number of factors, impacting the overall vulnerability of the affected parties to climate change (and other stressors).[130] When dealing with a multitude of both social and natural factors (e.g. connectivity, demography, economy, agricultural strategies, soil productivity, water availability), we need also to consider that

[117] See also Palmisano *et al.* 2019.

[118] Di Rita & Magri 2019, 245–248.

[119] Aranbarri *et al.* 2020, 10–12.

[120] Connor *et al.* 2019, 894–896, which is in line with the strong human impact on vegetation history during the El Argar period (Azuara *et al.* 2020, 8–14) as noted above.

[121] Finné *et al.* 2019.

[122] Schirrmacher *et al.* 2020. Notably, given discussions above, using decreasing AP percentages as a climate proxy reflecting decreasing winter precipitation (Schirrmacher *et al.* 2020, 5).

[123] Weiberg & Finné 2018, 590.

[124] Allcock 2017; Weiberg & Finné 2018.

[125] Tinner *et al.* 2016; Servera-Vives *et al.* 2018, 20–21; Jouffroy-Bapicot *et al.* 2021.

[126] Flohr *et al.* 2016.

[127] Marston & Branting 2016; Primavera *et al.* 2017; Dibble & Finné 2021.

[128] Junge *et al.* 2018; Kaptijn & Ertsen 2019; Brandolini & Carrer 2021.

[129] Jarriel 2021.

[130] Flohr *et al.* 2016, 35; Contreras *et al.* 2018b, 20–21.

these were unlikely to be equally distributed between—or within—societies and regions.[131] As concluded by Roberts *et al*., the Mediterranean landscape is a mosaic of regions with distinctive human-environment trajectories and it is imperative to analyse several scales reaching from the pan-Mediterranean to the very local (e.g. a coastal plain or an inland valley) to avoid making simplistic causal relationships.[132] Some but not all climate events led to notable socio-economic changes, and when they did, the effects were unequally distributed within and between societies. The actual impact and the coping strategies therefore differed between contexts. Large-scale syntheses need to be complemented by regional and local, and context-specific analyses, since simplified and monocausal explanations will never adequately address the complexity of human-environment-climate dynamics.[133]

Concluding remarks

Human-environment dynamics in past Mediterranean societies is a flourishing field of research. This review has sketched the outline of this particular field of study based on 280 separate articles published since 2016. This is by no means the totality of publications during these years, but we propose it to be a representative sample of a very diverse and expansive whole. The search strings favoured studies with some mention of climate, but the bibliometric search picked up an all-encompassing range of thematics. It is still obvious, however, that climate and climate change are prominent issues within Mediterranean human-environment dynamics. Scholarly consideration of these issues has a long history, but this review shows that the discussion on the role of climate and climate impact has matured. Monocausal models connecting climate events and societal collapse, for example, are increasingly replaced by scenarios favouring more nuanced renditions of the sequence of events within which internal societal factors are given more room for play. Still, evidence that shows clear chronological correlation between climate and societal change is mounting and an exclusion of the climate factor would decidedly reduce our understanding of the processes. It is also very clear that establishing causality remains a problem and thereby inhibits a full understanding of the exact mechanisms of change. One way to deal with this problem is to address change—whether human, environmental or climatic—from as many perspectives as possible and through multiple time-series, with attention to their comparability in space and time. As is clearly shown by the results of the selected articles, mechanisms of change in either domain may not look the same across time and space, and attention needs to be paid to the small-scale as well as to the large-scale.

We set out to investigate how well recent research on human-environment dynamics in the Mediterranean aligns with the grand challenges and priority research questions with which we began this article. Following this review, we would like to argue that considerable ground has been covered towards a better understanding of some of the issues raised. Much research has gone into the variable persistence of societies in the face of climate change, addressing different temporal and spatial scales. Important method development is ongoing in terms of the handling of uncertainties and comparability, as well as the development and utilization of new archaeological, environmental and climate proxies. Moving across both temporal and spatial scales allow scholars of past human-environment dynamics to approach different types of questions and different audiences. Interdisciplinarity is well established today as groups of scholars from a variety of disciplines meet over local and regional case-studies, even if best practice for such collaborative engagements remains under scrutiny. In parallel to these local and regional studies, however, we suggest that there is still room to use the context-specific results for broader and larger-scale comparisons between regions and time periods. Moreover, there is still a lack of studies addressing the role of social and environmental diversity within human-environment dynamics. Such diversity likely contributed to the capability of human societies to establish adaptive strategies in the face of climate change. Adaptive capacity is an important part of the overall vulnerability of past and present societies to external and internal stressors.[134] Here, we believe, there is more to be done, but also that the Mediterranean provides the necessary means to do it. Vulnerability assessments provide new avenues for research on human-environment dynamics in past (Mediterranean) societies and a common language between the past and the present. Along with the need for greater multiplicity and diversity of time-series data characterizing human societies and environmental factors, this is probably an essential (but largely untapped) next step to gain a fuller understanding of the variable persistence of human societies in the face of climate change and the overall workings of human-environment dynamics.

ERIKA WEIBERG
Department of Archaeology
and Ancient History
Uppsala University
Box 626
751 16 Uppsala, Sweden
erika.weiberg@antiken.uu.se

MARTIN FINNÉ
Department of Human Geography
Uppsala University
Box 513
751 20 Uppsala, Sweden
martin.finne@kultgeog.uu.se

131 Marston & Branting 2016; Bonnier & Finné 2020; Lawrence *et al.* 2021; Weinelt *et al.* 2021.
132 Roberts *et al.* 2019a, 934–935.
133 Clarke *et al.* 2016, 97, 117; Lespez *et al.* 2016, 240–241; Allcock 2017, 79–80.
134 Biggs *et al.* 2012; United Nations 2015; Kok *et al.* 2016.

Bibliography

Articles *not* among the selected *WoS* articles are marked by an asterisk (*). The bibliography lists the works referred to in the text. Full details of all the 280 *WoS* articles selected for the present study are available in *Supplemental Information* at https://doi.org/10.30549/opathrom-15-07.

Allcock, S.L. 2017. 'Long-term socio-environmental dynamics and adaptive cycles in Cappadocia, Turkey during the Holocene', *Quaternary International* 446, 66–82. https://doi.org/10.1016/j.quaint.2017.06.065

Aranbarri, J., M. Alcolea, E. Badal, S. Vila, E. Allué, M.J. Iriarte-Chiapusso, M. Sebastián, D. Magri & P. González-Sampériz 2020. 'Holocene history of Aleppo pine (*Pinus halepensis* Mill.) woodlands in the Ebro Basin (NE Spain). Climate-biased or human-induced?', *Review of Palaeobotany and Palynology* 279, 104240, 15 pp. https://doi.org/10.1016/j.revpalbo.2020.104240

Arıkan, B., F.B. Restelli & A. Masi 2016. 'Comparative modeling of Bronze Age land use in the Malatya Plain (Turkey)', *Quaternary Science Reviews* 136, 122–133. https://doi.org/10.1016/j.quascirev.2015.12.013

Arıkan, B. & T. Yıldırım 2018. 'Paleoclimate, geology, geomorphology, and Middle Holocene settlement systems in the Delice valley of north-central Anatolia', *JFA* 43:8, 570–590. https://doi.org/10.1080/00934690.2018.1535161

*Armstrong, C.G., A.C. Shoemaker, I. McKechnie, A. Ekblom, P. Szabó, P.J. Lane, A.C. McAlvay, O.J. Boles, S. Walshaw, N. Petek, K.S. Gibbons, E. Quintana Morales, E.N. Anderson, A. Ibragimow, G. Podruczny, J.C. Vamosi, T. Marks-Block, J.K. LeCompte, S. Awâsis, C. Nabess, P. Sinclair & C.L. Crumley 2017. 'Anthropological contributions to historical ecology. 50 questions, infinite prospects', *PLOS ONE* 12, e0171883, 26 pp. https://doi.org/10.1371/journal.pone.0171883

Azuara, J., V. Lebreton, L. Dezileau, A. Pérez Ruzafa & N. Combourieu-Nebout 2020. 'Middle and Late Holocene vegetation history of the Murcia region from a new high-resolution pollen sequence from the Mar Menor lagoon', *JAS Reports* 31, 102353, 16 pp. https://doi.org/10.1016/j.jasrep.2020.102353

Beffa, G., T. Pedrotta, D. Colombaroli, P.D. Henne, J.F.N. van Leeuwen, P. Süsstrunk, P. Kaltenrieder, C. Adolf, H. Vogel, S. Pasta, F.S. Anselmetti, E. Gobet & W. Tinner 2016. 'Vegetation and fire history of coastal north-eastern Sardinia (Italy) under changing Holocene climates and land use', *Vegetation History and Archaeobotany* 25, 271–289. https://doi.org/10.1007/s00334-015-0548-5

Berger, J.-F., S. Shennan, J. Woodbridge, A. Palmisano, F. Mazier, L. Nuninger, S. Guillon, E. Doyen, C. Begeot, V. Andrieu-Ponel, J. Azuara, A. Bevan, R. Fyfe & C.N. Roberts 2019. 'Holocene land cover and population dynamics in southern France', *The Holocene* 29, 776–798. https://doi.org/10.1177/0959683619826698

Bernigaud, N., A. Bondeau & J. Guiot 2021. 'Understanding the development of viticulture in Roman Gaul during and after the Roman climate optimum. The contribution of spatial analysis and agro-ecosystem modeling', *JAS Reports* 38, 103099, 9 pp. https://doi.org/10.1016/j.jasrep.2021.103099

Bevan, A., A. Palmisano, J. Woodbridge, R. Fyfe, C.N. Roberts & S. Shennan 2019. 'The changing face of the Mediterranean—Land cover, demography and environmental change. Introduction and overview', *The Holocene* 29, 703–707. https://doi.org/10.1177/0959683619826688

*Biggs, R., M. Schlüter, D. Biggs, E.L. Bohensky, S. BurnSilver, G. Cundill, V. Dakos, T.M. Daw, L.S. Evans, K. Kotschy, A.M. Leitch, C. Meek, A. Quinlan, C. Raudsepp-Hearne, M.D. Robards, M.L. Schoon, L. Schultz & P.C. West 2012. 'Toward principles for enhancing the resilience of ecosystem services', *Annual Review of Environment and Resources* 37, 421–448. https://doi.org/10.1146/annurev-environ-051211-123836

Bini, M., G. Zanchetta, E. Regattieri, I. Isola, R.N. Drysdale, F. Fabiani, S. Genovesi & J.C. Hellstrom 2020. 'Hydrological changes during the Roman Climatic Optimum in northern Tuscany (central Italy) as evidenced by speleothem records and archaeological data', *Journal of Quaternary Science* 35, 791–802. https://doi.org/10.1002/jqs.3224

*Bintliff, J. 2002. 'Time, process and catastrophism in the study of Mediterranean alluvial history. A review', *WorldArch* 33:3, 417–435. https://doi.org/10.1080/00438240120107459

Blanco-González, A., K.T. Lillios, J.A. López-Sáez & B.L. Drake 2018. 'Cultural, demographic and environmental dynamics of the Copper and Early Bronze Age in Iberia (3300–1500 BC). Towards an interregional multiproxy comparison at the time of the 4.2 ky BP event', *Journal of World Prehistory* 31, 1–79. https://doi.org/10.1007/s10963-018-9113-3

*Bogaard, A., R. Fraser, T.H.E. Heaton, M. Wallace, P. Vaiglova, M. Charles, G. Jones, R.P. Evershed, A.K. Styring, N.H. Andersen, R.-M. Arbogast, L. Bartosiewicz, A. Gardeisen, M. Kanstrup, U. Maier, E. Marinova, L. Ninov, M. Schäfer & E. Stephan 2013. 'Crop manuring and intensive land management by Europe's first farmers', *Proceedings of the National Academy of Sciences* 110, 12589–12594. https://doi.org/10.1073/pnas.1305918110

Bonnier, A. & M. Finné 2020. 'Climate variability and landscape dynamics in the Late Hellenistic and Roman north-eastern Peloponnese', *Antiquity* 94, 1482–1500. https://doi.org/10.15184/aqy.2020.34

Bouchaud, C., C. Jacquat & D. Martinoli 2017. 'Landscape use and fruit cultivation in Petra (Jordan) from Early Nabataean to Byzantine times (2nd century BC–5th century AD)', *Vegetation History and Archaeobotany* 26, 223–244. https://doi.org/10.1007/s00334-016-0582-y

Braje, T.J., T.P. Leppard, S.M. Fitzpatrick & J.M. Erlandson 2017. 'Archaeology, historical ecology and anthropogenic island ecosystems', *Environmental Conservation* 44:3, 286–297. https://doi.org/10.1017/S0376892917000261

Brandolini, F. & F. Carrer 2021. '*Terra, silva et paludes*. Assessing the role of alluvial geomorphology for Late-Holocene settlement strategies (Po Plain—N Italy) through point pattern analysis', *Environmental Archaeology* 26:5, 511–525. https://doi.org/10.1080/14614103.2020.1740866

*Brown, A., K. Walsh, D. Fallu, S. Cucchiaro & P. Tarolli 2020. 'European agricultural terraces and lynchets. From archaeological theory to heritage management', *WorldArch* 52:4, 566–588. https://doi.org/10.1080/00438243.2021.1891963

Bruins, H.J., H. Bithan-Guedj & T. Svoray 2019. 'GIS-based hydrological modelling to assess runoff yields in ancient-agricultural terraced wadi fields (central Negev desert)', *Journal of Arid Environments* 166, 91–107. https://doi.org/10.1016/j.jaridenv.2019.02.010

*Butzer, K.W. 2005. 'Environmental history in the Mediterranean world. Cross-disciplinary investigation of cause-and-effect for degradation and soil erosion', *JAS* 32:12, 1773–1800. https://doi.org/10.1016/j.jas.2005.06.001

Caracuta, V. 2020. 'Olive growing in Puglia (southeastern Italy). A review of the evidence from the Mesolithic to the Middle Ages', *Vegetation History and Archaeobotany* 29, 595–620. https://doi.org/10.1007/s00334-019-00765-y

Clarke, J., N. Brooks, E.B. Banning, M. Bar-Matthews, S. Campbell, L. Clare, M. Cremaschi, S. di Lernia, N. Drake, M. Gallinaro, S. Manning, K. Nicoll, G. Philip, S. Rosen, U.-D. Schoop, M.A. Tafuri, B. Weninger & A. Zerboni 2016. 'Climatic changes and social transformations in the Near East and North Africa during the "long" 4th millennium BC. A comparative study of environmental and archaeological evidence', *Quaternary Science Reviews* 136, 96–121. https://doi.org/10.1016/j.quascirev.2015.10.003

Connor, S.E., B. Vannière, D. Colombaroli, R.S. Anderson, J.S. Carrión, A. Ejarque, G. Gil Romera, P. González-Sampériz, D. Hoefer, C. Morales-Molino, J. Revelles, H. Schneider, W.O. van der Knaap, J.F. van Leeuwen & J. Woodbridge 2019. 'Humans take control of fire-driven diversity changes in Mediterranean Iberia's vegetation during the Mid–Late Holocene', *The Holocene* 29, 886–901. https://doi.org/10.1177/0959683619826652

*Contreras, D.A. 2017. 'Correlation is not enough—building better arguments in the archaeology of human-environment interactions', in *The archaeology of human-environment interactions. Strategies for investigating anthropogenic landscapes, dynamic environments, and climate change in the human past*, ed. D.A. Contreras, New York, 3–22.

Contreras, D.A., J. Guiot, R. Suarez & A. Kirman 2018a. 'Reaching the human scale. A spatial and temporal downscaling approach to the archaeological implications of paleoclimate data', *JAS* 93, 54–67. https://doi.org/10.1016/j.jas.2018.02.013

Contreras, D.A., E. Hiriart, A. Bondeau, A. Kirman, J. Guiot, L. Bernard, R. Suarez & S. Van Der Leeuw 2018b. 'Regional paleoclimates and local consequences. Integrating GIS analysis of diachronic settlement patterns and process-based agroecosystem modeling of potential agricultural productivity in Provence (France)', *PLOS ONE* 13, e0207622, 27 pp. https://doi.org/10.1371/journal.pone.0207622

Contreras, D.A., A. Bondeau, J. Guiot, A. Kirman, E. Hiriart, L. Bernard, R. Suarez & M. Fader 2019. 'From paleoclimate variables to prehistoric agriculture. Using a process-based agro-ecosystem model to simulate the impacts of Holocene climate change on potential agricultural productivity in Provence, France', *Quaternary International* 501:B, 303–316. https://doi.org/10.1016/j.quaint.2018.02.019

*Cookson, E., D.J. Hill & D. Lawrence 2019. 'Impacts of long term climate change during the collapse of the Akkadian Empire', *JAS* 106, 1–9. https://doi.org/10.1016/j.jas.2019.03.009

Cremaschi, M., A.M. Mercuri, P. Torri, A. Florenzano, C. Pizzi, M. Marchesini & A. Zerboni 2016. 'Climate change versus land management in the Po Plain (northern Italy) during the Bronze Age. New insights from the VP/VG sequence of the Terramara Santa Rosa di Poviglio', *Quaternary Science Reviews* 136, 153–172. https://doi.org/10.1016/j.quascirev.2015.08.011

D'Auria, A., M.P. Buonincontri, E. Allevato, A. Saracino, R. Jung, M. Pacciarelli & G. Di Pasquale 2017. 'Evidence of a short-lived episode of olive (*Olea europaea* L.) cultivation during the Early Bronze Age in western Mediterranean (southern Italy)', *The Holocene* 27, 605–612. https://doi.org/10.1177/0959683616670218

Dean, S., B.P. Horton, N. Evelpidou, N. Cahill, G. Spada & D. Sivan 2019. 'Can we detect centennial sea-level variations over the last three thousand years in Israeli archaeological records?', *Quaternary Science Reviews* 210, 125–135. https://doi.org/10.1016/j.quascirev.2019.02.021

*Decker, M.J. 2017. 'Approaches to the environmental history of Late Antiquity, part II. Climate change and the end of the Roman Empire', *History Compass* 15, e12425, 8 pp. https://doi.org/10.1111/hic3.12425

Deckers, K. 2016. 'Oak charcoal from northeastern Syria as proxy for vegetation, land use and climate in the second half of the Holocene', *Review of Palaeobotany and Palynology* 230, 22–36. https://doi.org/10.1016/j.revpalbo.2016.03.001

*Degroot, D., K. Anchukaitis, M. Bauch, J. Burnham, F. Carnegy, J. Cui, K. de Luna, P. Guzowski, G. Hambrecht, H. Huhtamaa, A. Izdebski, K. Kleemann, E. Moesswilde, N. Neupane, T. Newfield, Q. Pei, E. Xoplaki & N. Zappia 2021. 'Towards a rigorous understanding of societal responses to climate change', *Nature* 591, 539–550. https://doi.org/10.1038/s41586-021-03190-2

Di Rita, F. & D. Magri 2019. 'The 4.2 ka event in the vegetation record of the central Mediterranean', *Climate of the Past* 15, 237–251. https://doi.org/10.5194/cp-15-237-2019

Dibble, F. & M. Finné 2021. 'Socioenvironmental change as a process. Changing foodways as adaptation to climate change in south Greece from the Late Bronze Age to the Early Iron Age', *Quaternary International* 597, 50–62. https://doi.org/10.1016/j.quaint.2021.04.024

Dotsika, E. & G. Diamantopoulos 2019. 'Influence of climate on stable nitrogen isotopic values of contemporary Greek samples. Implications for isotopic studies of human remains from Neolithic to Late Bronze Age Greece', *Geosciences* 9:5, 217, 12 pp. https://doi.org/10.3390/geosciences9050217

Drake, B.L., A. Blanco-González & K.T. Lillios 2017. 'Regional demographic dynamics in the Neolithic transition in Iberia. Results from summed calibrated date analysis', *Journal of Archaeological Method and Theory* 24, 796–812. https://doi.org/10.1007/s10816-016-9286-y

Enrich, L.B. de L. & M. Mejías 2017. 'The hydrogeological and paleoclimatic factors in the Bronze Age Motillas Culture of La Mancha (Spain). The first hydraulic culture in Europe', *Hydrogeology Journal* 25, 1931–1950. https://doi.org/10.1007/s10040-017-1607-z

Finkelstein, I. & D. Langgut 2018. 'Climate, settlement history, and olive cultivation in the Iron Age southern Levant', *BASOR* 379, 153–169. https://doi.org/10.5615/bullamerschoorie.379.0153

*Finné, M. & E. Weiberg 2018. 'Climate change and ancient societies. Facing up to the challenge of chronological control', in *The resilience of heritage. Cultivating a future of the past. Essays in honour of Professor Paul Sinclair* (Studies in Global Archaeology, 23), eds. A. Ekblom, C. Isendahl & K.-J. Lindholm, Uppsala, 269–287.

Finné, M., J. Woodbridge, I. Labuhn & C.N. Roberts 2019. 'Holocene hydro-climatic variability in the Mediterranean. A synthetic multi-proxy reconstruction', *The Holocene* 29, 847–863. https://doi.org/10.1177/0959683619826634

Flohr, P., D. Fleitmann, R. Matthews, W. Matthews & S. Black 2016. 'Evidence of resilience to past climate change in southwest Asia. Early farming communities and the 9.2 and 8.2 ka events', *Quaternary Science Reviews* 136, 23–39. https://doi.org/10.1016/j.quascirev.2015.06.022

French, C., S. Taylor, R. McLaughlin, A. Cresswell, T. Kinnaird, D. Sanderson, S. Stoddart & C. Malone 2018. 'A Neolithic palaeo-catena for the Xagħra Upper Coralline Limestone Plateau of Gozo, Malta, and its implications for past soil development and land use', *CATENA* 171, 337–358. https://doi.org/10.1016/j.catena.2018.07.039

*Fyfe, R.M., J. Woodbridge, A. Palmisano, A. Bevan, S. Shennan, F. Burjachs, B. Legarra Herrero, O. García Puchol, J.-S. Carrión, J. Revelles & C.N. Roberts 2019. 'Prehistoric palaeodemographics and regional land cover change in eastern Iberia', *The Holocene* 29, 799–815. https://doi.org/10.1177/0959683619826643

Gaastra, J.S., L. Welton, M. de Gruchy & D. Lawrence 2021. 'Landscapes, climate and choice. Examining patterns in animal provisioning across the Near East *c.* 13,000–0 BCE', *Quaternary International* 595, 54–87. https://doi.org/10.1016/j.quaint.2021.03.045

Galili, E., D. Langgut, J.F. Terral, O. Barazani, A. Dag, L. Kolska Horwitz, I. Ogloblin Ramirez, B. Rosen, M. Weinstein-Evron, S. Chaim, E. Kremer, S. Lev-Yadun, E. Boaretto, Z. Ben-Barak-Zelas & A. Fishman 2021. 'Early production of table olives at a mid-7th millennium BP submerged site off the Carmel coast (Israel)', *Science Reports* 11, 2218. https://doi.org/10.1038/s41598-020-80772-6

*García-Ruiz, J.M., J.I. López-Moreno, S.M. Vicente-Serrano, T. Lasanta–Martínez & S. Beguería 2011. 'Mediterranean water resources in a global change scenario', *Earth-Science Reviews* 105, 121–139. https://doi.org/10.1016/j.earscirev.2011.01.006

Gauthier, N. 2016. 'The spatial pattern of climate change during the spread of farming into the Aegean', *JAS* 75, 1–9. https://doi.org/10.1016/j.jas.2016.09.004

Geraga, M., G. Papatheodorou, C. Agouridis, H. Kaberi, M. Iatrou, D. Christodoulou, E. Fakiris, M. Prevenios, S. Kordella & G. Ferentinos 2017. 'Palaeoenvironmental implications of a marine geoarchaeological survey conducted in the SW Argosaronic Gulf, Greece', *JAS Reports* 12, 805–818. https://doi.org/10.1016/j.jasrep.2016.08.004

Ghilardi, M., D. Psomiadis, V. Andrieu-Ponel, M. Colleu, P. Sotiropoulos, F. Longo, A. Rossi, V. Amato, F. Gasse, L. Sinibaldi, M. Renard, A. Bicket, D. Delanghe, F. Demory & J. Fleury 2018. 'First evidence of a lake at ancient Phaistos (Messara Plain, south-central Crete, Greece). Reconstructing paleoenvironments and differentiating the roles of human land-use and paleoclimate from Minoan to Roman times', *The Holocene* 28, 1225–1244. https://doi.org/10.1177/0959683618771473

Glais, A., L. Lespez, B. Vannière & J.A. López-Sáez 2017. 'Human-shaped landscape history in NE Greece. A palaeoenvironmental perspective', *JAS Reports* 15, 405–422. https://doi.org/10.1016/j.jasrep.2017.06.017

Gogou, A., A. Izdebski & K. Holmgren 2016. Mediterranean Holocene Climate, Environment and Human Societies, *Quaternary Science Reviews* 136, 1–252. https://www.sciencedirect.com/journal/quaternary-science-reviews/vol/136/suppl/C

Gregoricka, L.A. & S.G. Sheridan 2017. 'Continuity or conquest? A multi-isotope approach to investigating identity in the Early Iron Age of the southern Levant', *American Journal of Physical Anthropology* 162:1, 73–89. https://doi.org/10.1002/ajpa.23086

Gzam, M., N. El Mejdoub & E.H. Boumaggard 2019. 'Tracing sea-level changes during the Mid-Holocene in the southern Mediterranean coast. An example from the Gulf of Gabes', *Sedimentary Geology* 391, 105516, 10 pp. https://doi.org/10.1016/j.sedgeo.2019.105516

*Haldon, J. & A. Rosen 2018. 'Society and environment in the east Mediterranean ca 300–1800 CE. Problems of resilience, adaptation and transformation. Introductory essay', *Human Ecology* 46, 275–290. https://doi.org/10.1007/s10745-018-9972-3

*Haldon, J., L. Mordechai, T.P. Newfield, A.F. Chase, A. Izdebski, P. Guzowski, I. Labuhn & N. Roberts 2018. 'History meets palaeoscience. Consilience and collaboration in studying past societal responses to environmental change', *Proceedings of the National Academy of Sciences* 115:13, 3210–3218. https://doi.org/10.1073/pnas.1716912115

*Haldon, J., A.F. Chase, W. Eastwood, M. Medina-Elizalde, A. Izdebski, F. Ludlow, G. Middleton, L. Mordechai, J. Nesbitt & B.L. Turner 2020. 'Demystifying collapse. Climate, environment, and social agency in pre-modern societies', *Millennium* 17, 1–33. https://doi.org/10.1515/mill-2020-0002

Holmgren, K., A. Gogou, A. Izdebski, J. Luterbacher, M.-A. Sicre & E. Xoplaki 2016. 'Mediterranean Holocene climate, environment and human societies', *Quaternary Science Reviews* 136, 1–4. https://doi.org/10.1016/j.quascirev.2015.12.014

*Hughes, R.E., E. Weiberg, A. Bonnier, M. Finné & J.O. Kaplan 2018. 'Quantifying land use in past societies from cultural practice and archaeological data', *Land* 7, 9, 21 pp. https://doi.org/10.3390/land7010009

*Huhtamaa, H. & F.C. Ljungqvist 2021. 'Climate in Nordic historical research—a research review and future perspectives', *Scandinavian Journal of History* 46:5, 665–695. https://doi.org/10.1080/03468755.2021.1929455

Izdebski, A., K. Holmgren, E. Weiberg, S.R. Stocker, U. Büntgen, A. Florenzano, A. Gogou, S.A.G. Leroy, J. Luterbacher, B. Martrat, A. Masi, A.M. Mercuri, P. Montagna, L. Sadori, A. Schneider, M.-A. Sicre, M. Triantaphyllou & E. Xoplaki 2016. 'Realising consilience. How better communication between archaeologists, historians and natural scientists can transform the study of past climate change in the Mediterranean', *Quaternary Science Reviews* 136, 5–22. https://doi.org/10.1016/j.quascirev.2015.10.038

Jalali, B. & M.-A. Sicre 2019. 'The 4.2 ka event in the Euro-Mediterranean region—a study from the MISTRALS/PALEOMEX program', in *Patterns and mechanisms of climate, paleoclimate and paleoenvironmental changes from low-latitude regions*, eds. Z. Zhang, N. Khélifi, A. Mezghani & E. Heggy, Cham, 13–15. https://doi.org/10.1007/978-3-030-01599-2_3

Jalali, B., M.-A. Sicre, J. Azuara, V. Pellichero & N. Combourieu-Nebout 2019. 'Influence of the North Atlantic subpolar gyre circulation on the 4.2 ka BP event', *Climate of the Past* 15:2, 701–711. https://doi.org/10.5194/cp-15-701-2019

Janssen, E., J. Poblome, J. Claeys, V. Kint, P. Degryse, E. Marinova & B. Muys 2017. 'Fuel for debating ancient economies. Calculating wood consumption at urban scale in Roman Imperial times', *JAS Reports* 11, 592–599. https://doi.org/10.1016/j.jasrep.2016.12.029

Jaouadi, S., V. Lebreton, V. Bout-Roumazeilles, G. Siani, R. Lakhdar, R. Boussoffara, L. Dezileau, N. Kallel, B. Mannai-Tayech & N. Combourieu-Nebout 2016. 'Environmental changes, climate and anthropogenic impact in south-east Tunisia during the last 8 kyr', *Climate of the Past* 12:6, 1339–1359. https://doi.org/10.5194/cp-12-1339-2016

Jarriel, K. 2021. 'Climate disaster and the resilience of local maritime networks. Two examples from the Aegean Bronze Age', *Quaternary International* 597, 118–130. https://doi.org/10.1016/j.quaint.2020.08.010

Jazwa, K.A. & C.S. Jazwa 2021. 'Architecture and storage in Mediterranean environments. Case studies from the Aegean and southern California', *Quaternary International* 597, 87–102. https://doi.org/10.1016/j.quaint.2020.09.007

Jouffroy-Bapicot, I., T. Pedrotta, M. Debret, S. Field, R. Sulpizio, G. Zanchetta, P. Sabatier, N. Roberts, W. Tinner, K. Walsh & B. Vannière 2021. 'Olive groves around the lake. A ten-thousand-year history of a Cretan landscape (Greece) reveals the dominant role of humans in making this Mediterranean ecosystem', *Quaternary Science Reviews* 267, 107072, 24 pp. https://doi.org/10.1016/j.quascirev.2021.107072

*Jung, R. & B. Weninger 2015. 'Archaeological and environmental impact of the 4.2 ka cal BP event in the central and eastern Mediterranean', in *2200 BC. Ein Klimasturz als Ursache für den Zerfall der Alten Welt? 7. Mitteldeutscher Archäologentag, vom 23. bis 26. Oktober 2014 in Halle (Saale)*, eds. H. Meller, H.W. Arz, R. Jung & R. Risch, Halle, Saale, 205–234.

Junge, A., J. Lomax, R. Shahack-Gross, I. Finkelstein & M. Fuchs 2018. 'Chronology of an ancient water reservoir and the history of human activity in the Negev Highlands, Israel', *Geoarchaeology* 33:6, 695–707. https://doi.org/10.1002/gea.21682

Kaniewski, D., N. Marriner, J. Bretschneider, G. Jans, C. Morhange, R. Cheddadi, T. Otto, F. Luce & E. Van Campo 2019. '300-year drought frames Late Bronze Age to Early Iron Age transition in the Near East. New palaeoecological data from Cyprus and Syria', *Regional Environmental Change* 19, 2287–2297. https://doi.org/10.1007/s10113-018-01460-w

Kaptijn, E. & M.W. Ertsen 2019. '"All sunshine makes a desert". Building interdisciplinary understanding of survival strategies of ancient communities in the arid Zerqa Triangle, Jordan Valley', *Journal of Arid Environments* 163, 114–126. https://doi.org/10.1016/j.jaridenv.2018.11.006

Katrantsiotis, C., E. Norström, K. Holmgren, J. Risberg & A. Skelton 2016. 'High-resolution environmental reconstruction in SW Peloponnese, Greece, covering the last *c*. 6000 years. Evidence from Agios Floros fen, Messenian Plain', *The Holocene* 26, 188–204. https://doi.org/10.1177/0959683615596838

Katrantsiotis, C., M.E. Kylander, R. Smittenberg, K.K.A. Yamoah, M. Hättestrand, P. Avramidis, N.A. Strandberg & E. Norström 2018. 'Eastern Mediterranean hydroclimate reconstruction over the last 3600 years based on sedimentary n-alkanes, their carbon and hydrogen isotope composition and XRF data from the Gialova lagoon, SW Greece', *Quaternary Science Reviews* 194, 77–93. https://doi.org/10.1016/j.quascirev.2018.07.008

Katrantsiotis, C., E. Norström, R.H. Smittenberg, M. Finné, E. Weiberg, M. Hättestrand, P. Avramidis & S. Wastegård 2019. 'Climate changes in the eastern Mediterranean over the last 5000 years and their links to the high-latitude atmospheric patterns and Asian monsoons', *Global and Planetary Change* 175, 36–51. https://doi.org/10.1016/j.gloplacha.2019.02.001

*Kintigh, K.W., J.H. Altschul, M.C. Beaudry, R.D. Drennan, A.P. Kinzig, T.A. Kohler, W.F. Limp, H.D.G. Maschner, W.K. Michener, T.R. Pauketat, P. Peregrine, J.A. Sabloff, T.J. Wilkinson, H.T. Wright & M.A. Zeder 2014. 'Grand challenges for archaeology', *American Antiquity* 79:1, 2014, pp. 5-24. https://doi.org/10.7183/0002-7316.79.1.5

Knapp, A.B. & S.W. Manning 2016. 'Crisis in context. The end of the Late Bronze Age in the eastern Mediterranean', *AJA* 120:1, 99–149. https://doi.org/10.3764/aja.120.1.0099

Knitter, D., G. Günther, W.B. Hamer, T. Kessler, J. Seguin, I. Unkel, E. Weiberg, R. Duttmann & O. Nakoinz 2019. 'Land use patterns and climate change—a modeled scenario of the Late Bronze Age in southern Greece', *Environmental Research Letters* 14, 125003, 11 pp. https://doi.org/10.1088/1748-9326/ab5126

*Kok, M., M. Lüdeke, P. Lucas, T. Sterzel, C. Walther, P. Janssen, D. Sietz & I. de Soysa 2016. 'A new method for analysing socio-ecological patterns of vulnerability', *Regional Environmental Change* 16, 229–243. https://doi.org/10.1007/s10113-014-0746-1

*Lane, P.J. 2015. 'Just how long does "long-term" have to be? Matters of temporal scale as impediments to interdisciplinary understanding in historical ecology', in *The Oxford handbook of historical ecology and applied archaeology*, eds. C. Isendahl & D. Stump, Oxford, 48–71. https://doi.org/10.1093/oxfordhb/9780199672691.013.5

*Langgut, D., R. Cheddadi, J.S. Carrión, M. Cavanagh, D. Colombaroli, W.J. Eastwood, R. Greenberg, T. Litt, A.M. Mercuri, A. Miebach, C.N. Roberts, H. Woldring & J. Woodbridge 2019. 'The origin and spread of olive cultivation in the Mediterranean Basin. The fossil pollen evidence', *The Holocene* 29, 902–922. https://doi.org/10.1177/0959683619826654

Lawrence, D., G. Philip, H. Hunt, L. Snape-Kennedy & T.J. Wilkinson 2016. 'Long term population, city size and climate trends in the Fertile Crescent. A first approximation', *PLOS ONE* 11, e0152563, 16 pp. https://doi.org/10.1371/journal.pone.0152563

Lawrence, D., A. Palmisano & M.W. de Gruchy 2021. 'Collapse and continuity. A multi-proxy reconstruction of settlement organization and population trajectories in the northern Fertile Crescent during the 4.2kya rapid climate change event', *PLOS ONE* 16, e0244871, 20 pp. https://doi.org/10.1371/journal.pone.0244871

Lespez, L., A. Glais, J.-A. Lopez-Saez, Y.L. Drezen, Z. Tsirtsoni, R. Davidson, L. Biree & D. Malamidou 2016. 'Middle Holocene rapid environmental changes and human adaptation in Greece', *Quaternary Research* 85:2, 227–244. https://doi.org/10.1016/j.yqres.2016.02.002

Lestienne, M., I. Jouffroy-Bapicot, D. Leyssenne, P. Sabatier, M. Debret, P.-J. Albertini, D. Colombaroli, J. Didier, C. Hély & B. Vannière 2019. 'Fires and human activities as key factors in the high diversity of Corsican vegetation', *The Holocene* 30:2, 244–257. https://doi.org/10.1177/0959683619883025

Lewis, J.P., M.J. Leng, J.R. Dean, A. Marciniak, D.E. Bar-Yosef Mayer & X. Wu 2017. 'Early Holocene palaeoseasonality inferred from the stable isotope composition of *Unio* shells from Çatalhöyük, Turkey', *Environmental Archaeology* 22:1, 79–95. https://doi.org/10.1080/14614103.2015.1116216

*Li, K., J. Rollins & E. Yan 2018. 'Web of Science use in published research and review papers 1997–2017. A selective, dynamic, cross-domain, content-based analysis', *Scientometrics* 115, 1–20. https://doi.org/10.1007/s11192-017-2622-5

Lillios, K.T., A. Blanco-González, B.L. Drake & J.A. López-Sáez 2016. 'Mid-Late Holocene climate, demography, and cultural dynamics in Iberia. A multi-proxy approach', *Quaternary Science Reviews* 135, 138–153. https://doi.org/10.1016/j.quascirev.2016.01.011

*Lionello, P. & L. Scarascia 2018. 'The relation between climate change in the Mediterranean region and global warming', *Regional Environmental Change* 18, 1481–1493. https://doi.org/10.1007/s10113-018-1290-1

Liritzis, I., A. Westra & C. Miao 2019. 'Disaster geoarchaeology and natural cataclysms in world cultural evolution. An overview', *Journal of Coastal Research* 35:6, 1307–1330. https://doi.org/10.2112/JCOASTRES-D-19-00035.1

*Ljungqvist, F.C., A. Seim & H. Huhtamaa 2021. 'Climate and society in European history', *WIREs Climate Change* 12:2, e691, 28 pp. https://doi.org/10.1002/wcc.691

López-Merino, L., N.R. Colás-Ruiz, M.F. Adame, O. Serrano, A. Martínez Cortizas & M.A. Mateo 2017. 'A six thousand-year record of climate and land-use change from Mediterranean seagrass mats', *Journal of Ecology* 105:5, 1267–1278. https://doi.org/10.1111/1365-2745.12741

López-Sáez, J.A., G. Vargas, J. Ruiz-Fernández, O. Blarquez, F. Alba-Sánchez, M. Oliva, S. Pérez-Díaz, S. Robles-López & D. Abel-Schaad 2018. 'Paleofire dynamics in central Spain during the Late Holocene. The role of climatic and anthropogenic forcing. Paleofire Gredos Range', *Land Degradation & Development* 29:7, 2045–2059. https://doi.org/10.1002/ldr.2751

*Luterbacher, J. & C. Pfister 2015. 'The year without a summer', *Nature Geoscience* 8, 246–248. https://doi.org/10.1038/ngeo2404

Marignani, M., A. Chiarucci, L. Sadori & A.M. Mercuri 2017. 'Natural and human impact in Mediterranean landscapes. An intriguing puzzle or only a question of time?', *Plant Biosystems—An International Journal Dealing with all Aspects of Plant Biology* 151:5, 900–905. https://doi.org/10.1080/11263504.2016.1244121

Marinova, E. & M. Ntinou 2018. 'Neolithic woodland management and land-use in south-eastern Europe. The anthracological evidence from northern Greece and Bulgaria', *Quaternary International* 496, 51–67. https://doi.org/10.1016/j.quaint.2017.04.004

Marriner, N., D. Kaniewski, T. Gambin, B. Gambin, B. Vannière, C. Morhange, M. Djamali, K. Tachikawa, V. Robin, D. Rius & E. Bard 2019. 'Fire as a motor of rapid environmental degradation during the earliest peopling of Malta 7500 years ago', *Quaternary Science Reviews* 212, 199–205. https://doi.org/10.1016/j.quascirev.2019.03.001

Marston, J.M. & S. Branting 2016. 'Agricultural adaptation to highland climate in Iron Age Anatolia', *JAS Reports* 9, 25–32. https://doi.org/10.1016/j.jasrep.2016.06.050

*Marx, W., R. Haunschild & L. Bornmann 2018. 'Climate and the decline and fall of the Western Roman Empire. A bibliometric view on an interdisciplinary approach to answer a most classic historical question', *Climate* 6:4, 90. https://doi.org/10.3390/cli6040090

Masi, A., F. Balossi Restelli, D. Sabato, C. Vignola & L. Sadori 2018. 'Timber exploitation during the 5th–3rd millennia BCE at Arslantepe (Malatya, Turkey). Environmental constraints and cultural choices', *Archaeological and Anthropological Sciences* 10, 465–483. https://doi.org/10.1007/s12520-017-0499-0

Meister, J., R. Rettig & B. Schütt 2018. 'Ancient runoff agriculture at Early Bronze Age Jawa (Jordan). Water availability, efficiency and food supply capacity', *JAS Reports* 22, 359–371. https://doi.org/10.1016/j.jasrep.2016.06.033

*Mercuri, A.M., A. Florenzano, F. Burjachs, M. Giardini, K. Kouli, A. Masi, L. Picornell-Gelabert, J. Revelles, L. Sadori, G. Servera-Vives, P. Torri & R. Fyfe 2019a. 'From influence to impact. The multifunctional land use in Mediterranean prehistory emerging from palynology of archaeological sites (8.0–2.8 ka BP)', *The Holocene* 29, 830–846. https://doi.org/10.1177/0959683619826631

Mercuri, A.M., A. Florenzano, R. Terenziani, E. Furia, D. Dallai & P. Torri 2019b. 'Middle- to Late-Holocene fire history and the impact on Mediterranean pine and oak forests according to the core RF93-30, central Adriatic Sea', *The Holocene* 29, 1362–1376. https://doi.org/10.1177/0959683619846982

*Middleton, G.D. 2012. 'Nothing lasts forever. Environmental discourses on the collapse of past societies', *Journal of Archaeological Research* 20, 257–307. https://doi.org/10.1007/s10814-011-9054-1

Miebach, A., P. Niestrath, P. Roeser & T. Litt 2016. 'Impacts of climate and humans on the vegetation in northwestern Turkey. Palynological insights from Lake Iznik since the Last Glacial', *Climate of the Past* 12, 575–593. https://doi.org/10.5194/cp-12-575-2016

Mora-González, A., A. Delgado-Huertas, A. Granados-Torres, F. Contreras Cortés, I. Pavón Soldevila & D. Duque Espino 2018. 'Complex agriculture during the second millennium BC. Isotope composition of carbon studies (δ13C) in archaeological plants of the settlement Cerro del Castillo de Alange (SW Iberian peninsula, Spain)', *Vegetation History and Archaeo-*

botany 27, 453–462.
https://doi.org/10.1007/s00334-017-0634-y

Mora-González, A., R. Fernandes, F. Contreras Cortés, A. Granados-Torres, E. Alarcón García & A. Delgado-Huertas 2019. 'Reporting atmospheric CO2 pressure corrected results of stable carbon isotope analyses of cereals remains from the archaeological site of Peñalosa (SE Iberian peninsula). Agricultural and social implications', *Archaeological and Anthropological Sciences* 11, 1995–2005.
https://doi.org/10.1007/s12520-018-0650-6

Morales-Molino, C., M. Steffen, S. Samartin, J.F.N. van Leeuwen, D. Hürlimann, E. Vescovi & W. Tinner 2021. 'Long-term responses of Mediterranean mountain forests to climate change, fire and human activities in the northern Apennines (Italy)', *Ecosystems* 24, 1361–1377.
https://doi.org/10.1007/s10021-020-00587-4

Moreno-de-las-Heras, M., F. Lindenberger, J. Latron, N. Lana-Renault, P. Llorens, J. Arnáez, A. Romero-Díaz & F. Gallart 2019. 'Hydro-geomorphological consequences of the abandonment of agricultural terraces in the Mediterranean region. Key controlling factors and landscape stability patterns', *Geomorphology* 333, 73–91.
https://doi.org/10.1016/j.geomorph.2019.02.014

Morrison, K.D., E. Hammer, O. Boles, M. Madella, N. Whitehouse, M.-J. Gaillard, J. Bates, M.V. Linden, S. Merlo, A. Yao, L. Popova, A.C. Hill, F. Antolin, A. Bauer, S. Biagetti, R.R. Bishop, P. Buckland, P. Cruz, D. Dreslerová, G. Dusseldorp, E. Ellis, D. Filipovic, T. Foster, M.J. Hannaford, S.P. Harrison, M. Hazarika, H. Herold, J. Hilpert, J.O. Kaplan, A. Kay, K.K. Goldewijk, J. Kolář, E. Kyazike, J. Laabs, C. Lancelotti, P. Lane, D. Lawrence, K. Lewis, U. Lombardo, G. Lucarini, M. Arroyo-Kalin, R. Marchant, F. Mayle, M. McClatchie, M. McLeester, S. Mooney, M.M. Hoyo, V. Navarrete, E. Ndiema, E.G. Neves, M. Nowak, W.A. Out, C. Petrie, L.N. Phelps, Z. Pinke, S. Rostain, T. Russell, A. Sluyter, A.K. Styring, E. Tamanaha, E. Thomas, S. Veerasamy, L. Welton & M. Zanon 2021. 'Mapping past human land use using archaeological data. A new classification for global land use synthesis and data harmonization', *PLOS ONE* 16, e0246662, 38 pp.
https://doi.org/10.1371/journal.pone.0246662

Moser, D., G. Di Pasquale, F. Scarciglia & O. Nelle 2017. 'Holocene mountain forest changes in central Mediterranean. Soil charcoal data from the Sila Massif (Calabria, southern Italy)', *Quaternary International* 457, 113–130.
https://doi.org/10.1016/j.quaint.2017.01.042

*Nelson, M.C., S.E. Ingram, A.J. Dugmore, R. Streeter, M.A. Peeples, T.H. McGovern, M. Hegmon, J. Arneborg, K.W. Kintigh, S. Brewington, K.A. Spielmann, I.A. Simpson, C. Strawhacker, L.E.L. Comeau, A. Torvinen, C.K. Madsen, G. Hambrecht & K. Smiarowski 2016. 'Climate challenges, vulnerabilities, and food security', *Proceedings of the National Academy of Sciences* 113:2, 298–303.
https://doi.org/10.1073/pnas.1506494113

*Nitsch, E., S. Andreou, A. Creuzieux, A. Gardeisen, P. Halstead, V. Isaakidou, A. Karathanou, D. Kotsachristou, D. Nikolaidou, A. Papanthimou, C. Petridou, S. Triantaphyllou, S.M. Valamoti, A. Vasileiadou & A. Bogaard 2017. 'A bottom-up view of food surplus. Using stable carbon and nitrogen isotope analysis to investigate agricultural strategies and diet at Bronze Age Archontiko and Thessaloniki Toumba, northern Greece', *WorldArch* 49:1, 105–137.
https://doi.org/10.1080/00438243.2016.1271745

Norström, E., C. Katrantsiotis, M. Finné, J. Risberg, R.H. Smittenberg & S. Bjursäter 2018. 'Biomarker hydrogen isotope composition (δD) as proxy for Holocene hydro-climatic change and seismic activity in SW Peloponnese, Greece', *Journal of Quaternary Science* 33:5, 563–574.
https://doi.org/10.1002/jqs.3036

Norström, E., J. West, K. Kouli, C. Katrantsiotis, M. Hättestrand & R.H. Smittenberg 2021. 'Evaluation of anhydrosugars as a molecular proxy for paleofire activity. A case study on a Holocene sediment core from Agios Floros, Peloponnese, Greece', *Organic Geochemistry* 153, 104193, 10 pp.
https://doi.org/10.1016/j.orggeochem.2021.104193

Ocakoğlu, F., Ç. Çilingiroğlu, İ.P. Erkara, S. Ünan, B. Dinçer & M.S. Akkiraz 2019. 'Human-climate interactions since the Neolithic period in central Anatolia. Novel multi-proxy data from the Kureyşler area, Kütahya, Turkey', *Quaternary Science Reviews* 213, 1–17.
https://doi.org/10.1016/j.quascirev.2019.04.016

*OECD. n.d. 'Gross domestic spending on R&D (indicator)'.
https://doi.org/10.1787/d8b068b4-en

*Palmisano, A., A. Bevan & S. Shennan 2017. 'Comparing archaeological proxies for long-term population patterns. An example from central Italy', *JAS* 87, 59–72.
https://doi.org/10.1016/j.jas.2017.10.001

Palmisano, A., J. Woodbridge, C.N. Roberts, A. Bevan, R. Fyfe, S. Shennan, R. Cheddadi, R. Greenberg, D. Kaniewski, D. Langgut, S.A. Leroy, T. Litt & A. Miebach 2019. 'Holocene landscape dynamics and long-term population trends in the Levant', *The Holocene* 29, 708–727. https://doi.org/10.1177/0959683619826642

*Palmisano, A., A. Bevan, A. Kabelindde, N. Roberts & S. Shennan 2021a. 'Long-term demographic trends in prehistoric Italy. Climate impacts and regionalised socio-ecological trajectories', *Journal of World Prehistory* 34, 381–432. https://doi.org/10.1007/s10963-021-09159-3

Palmisano, A., D. Lawrence, M.W. de Gruchy, A. Bevan & S. Shennan 2021b. 'Holocene regional population dynamics and climatic trends in the Near East. A first comparison using archaeo-demographic proxies', *Quaternary Science Reviews* 252, 106739. https://doi.org/10.1016/j.quascirev.2020.106739

*Parkinson, E.W., T.R. McLaughlin, C. Esposito, S. Stoddart & C. Malone 2021. 'Radiocarbon dated trends and central Mediterranean prehistory', *Journal of World Prehistory* 34, 317–379. https://doi.org/10.1007/s10963-021-09158-4

Pedrotta, T., E. Gobet, C. Schwörer, G. Beffa, C. Butz, P.D. Henne, C. Morales-Molino, S. Pasta, J.F.N. van Leeuwen, H. Vogel, E. Zwimpfer, F.S. Anselmetti, M. Grosjean & W. Tinner 2021. '8,000 years of climate, vegetation, fire and land-use dynamics in the thermo-Mediterranean vegetation belt of northern Sardinia (Italy)', *Vegetation History and Archaeobotany* 30, 789–813. https://doi.org/10.1007/s00334-021-00832-3

Pennos, C., S. Pechlivanidou, E. Aidona, A. Bourliva, S.-E. Lauritzen, R. Scholger & N. Kantiranis 2021. 'Decoding short-term climatic variations from cave sediments over the Mid-Holocene. Implications for human occupation in the Katarraktes Cave system, northern Greece', *Zeitschrift für Geomorphologie* 63:1, 67–80. https://doi.org/10.1127/zfg/2021/0680

*Pesta, B., J. Fuerst & E. Kirkegaard 2018. 'Bibliometric keyword analysis across seventeen years (2000–2016) of intelligence articles', *Journal of Intelligence* 6:4, 46, 12 pp. https://doi.org/10.3390/jintelligence6040046

Picornell-Gelabert, L., G. Servera-Vives, Y. Carrión Marco, F. Burjachs, A. Currás, Y. Llergo, A. Dufraisse, M. De Luís Arrillaga & M. Mus Amézquita 2021. 'Late Holocene Aleppo pine (*Pinus halepensis* Miller) woodlands in Mallorca (Balearic Islands, western Mediterranean). Investigation of their distribution and the role of human management based on anthracological, dendro-anthracological and archaeopalynological data', *Quaternary International* 593–594, 346–363. https://doi.org/10.1016/j.quaint.2020.11.006

Pleuger, E., J.-P. Goiran, I. Mazzini, H. Delile, A. Abichou, A. Gadhoum, H. Djerbi, N. Piotrowska, A. Wilson, E. Fentress, I. Ben Jerbania & N. Fagel 2019. 'Palaeogeographical and palaeoenvironmental reconstruction of the Medjerda delta (Tunisia) during the Holocene', *Quaternary Science Reviews* 220, 263–278. https://doi.org/10.1016/j.quascirev.2019.07.017

Post, R. 2017. 'The environmental history of Classical and Hellenistic Greece. The contribution of environmental archaeology', *History Compass* 15:10, e12392, 12 pp. https://doi.org/10.1111/hic3.12392

Prendergast, A.L., A.J.E. Pryor, H. Reade & R.E. Stevens 2018. 'Seasonal records of palaeoenvironmental change and resource use from archaeological assemblages', *JAS Reports* 21, 1191–1197. https://doi.org/10.1016/j.jasrep.2018.08.006

Primavera, M., C. D'Oronzo, I.M. Muntoni, F. Radina & G. Fiorentino 2017. 'Environment, crops and harvesting strategies during the II millennium BC. Resilience and adaptation in socio-economic systems of Bronze Age communities in Apulia (SE Italy)', *Quaternary International* 436:B, 83–95. https://doi.org/10.1016/j.quaint.2015.05.070

Pustovoytov, K. & S. Riehl 2016. 'The Early Bronze Age/Middle Bronze Age transition and the aquifer geography in the Near East', *JAS* 69, 1–11. https://doi.org/10.1016/j.jas.2016.02.005

Rapuc, W., P. Sabatier, F. Arnaud, A. Palumbo, A.-L. Develle, J.-L. Reyss, L. Augustin, E. Régnier, A. Piccin, E. Chapron, J.-P. Dumoulin & U. von Grafenstein 2019. 'Holocene-long record of flood frequency in the southern Alps (Lake Iseo, Italy) under human and climate forcing', *Global and Planetary Change* 175, 160–172. https://doi.org/10.1016/j.gloplacha.2019.02.010

*Roberts, N., W.J. Eastwood, C. Kuzucuoglu, G. Fiorentino & V. Caracuta 2011. 'Climatic, vegetation and cultural change in the eastern Mediterranean during the Mid-Holocene environmental transition', *The Holocene* 21, 147–162. https://doi.org/10.1177/0959683610386819

Roberts, C.N., J. Woodbridge, A. Palmisano, A. Bevan, R. Fyfe & S. Shennan 2019a. 'Mediterranean landscape change during the Holocene. Synthesis, comparison and regional trends in population, land cover and climate', *The Holocene* 29, 923–937. https://doi.org/10.1177/0959683619826697

Roberts, N., S.L. Allcock, H. Barnett, A. Mather, W.J. Eastwood, M. Jones, N. Primmer, H. Yiğitbaşıoğlu & B. Vannière 2019b. 'Cause-and-effect in Mediterranean erosion. The role of humans and climate upon Holocene sediment flux into a central Anatolian lake catchment', *Geomorphology* 331, 36–48. https://doi.org/10.1016/j.geomorph.2018.11.016

Ronen, A. & G. Almagor 2021. 'Climate, sea level and culture in the southeastern Mediterranean 20–4 ky BP', *L'Anthropologie* 125:2, 102858. https://doi.org/10.1016/j.anthro.2021.102858

Schirrmacher, J., J. Kneisel, D. Knitter, W. Hamer, M. Hinz, R.R. Schneider & M. Weinelt 2020. 'Spatial patterns of temperature, precipitation, and settlement dynamics on the Iberian peninsula during the Chalcolithic and the Bronze Age', *Quaternary Science Reviews* 233, 106220, 17 pp. https://doi.org/10.1016/j.quascirev.2020.106220

*Seddon, A.W.R., A.W. Mackay, A.G. Baker, H.J.B. Birks, E. Breman, C.E. Buck, E.C. Ellis, C.A. Froyd, J.L. Gill, L. Gillson, E.A. Johnson, V.J. Jones, S. Juggins, M. Macias-Fauria, K. Mills, J.L. Morris, D. Nogués-Bravo, S.W. Punyasena, T.P. Roland, A.J. Tanentzap, K.J. Willis, M. Aberhan, E.N. van Asperen, W.E.N. Austin, R.W. Battarbee, S. Bhagwat, C.L. Belanger, K.D. Bennett, H.H. Birks, C.B. Ramsey, S.J. Brooks, M. de Bruyn, P.G. Butler, F.M. Chambers, S.J. Clarke, A.L. Davies, J.A. Dearing, T.H.G. Ezard, A. Feurdean, R.J. Flower, P. Gell, S. Hausmann, E.J. Hogan, M.J. Hopkins, E.S. Jeffers, A.A. Korhola, R. Marchant, T. Kiefer, M. Lamentowicz, I. Larocque-Tobler, L. López-Merino, L.H. Liow, S. McGowan, J.H. Miller, E. Montoya, O. Morton, S. Nogué, C. Onoufriou, L.P. Boush, F. Rodriguez-Sanchez, N.L. Rose, C.D. Sayer, H.E. Shaw, R. Payne, G. Simpson, K. Sohar, N.J. Whitehouse, J.W. Williams & A. Witkowski 2014. 'Looking forward through the past. Identification of 50 priority research questions in palaeoecology', *Journal of Ecology* 102:1, 256–267. https://doi.org/10.1111/1365-2745.12195

Seguin, J., J.L. Bintliff, P.M. Grootes, T. Bauersachs, W. Dörfler, C. Heymann, S.W. Manning, S. Müller, M.-J. Nadeau, O. Nelle, P. Steier, J. Weber, E.-M. Wild, E. Zagana & I. Unkel 2019. '2500 years of anthropogenic and climatic landscape transformation in the Stymphalia polje, Greece', *Quaternary Science Reviews* 213, 133–154. https://doi.org/10.1016/j.quascirev.2019.04.028

Seguin, J., P. Avramidis, W. Dörfler, A. Emmanouilidis & I. Unkel 2020a. 'A 2600-year high-resolution climate record from Lake Trichonida (SW Greece)', *E&G Quaternary Science Journal* 69:2, 139–160. https://doi.org/10.5194/egqsj-69-139-2020

*Seguin, J., P. Avramidis, A. Haug, T. Kessler, A. Schimmelmann & I. Unkel 2020b. 'Reconstruction of palaeoenvironmental variability based on an intercomparison of four lacustrine archives on the Peloponnese (Greece) for the last 5000 years', *E&G Quaternary Science Journal* 69:2, 165–186. https://doi.org/10.5194/egqsj-69-165-2020

Şenkul, Ç., T. Memiş, W.J. Eastwood & U. Doğan 2018. 'Mid-to Late-Holocene paleovegetation change in vicinity of Lake Tuzla (Kayseri), central Anatolia, Turkey', *Quaternary International* 486, 98–106. https://doi.org/10.1016/j.quaint.2018.05.026

Servera-Vives, G., S. Riera, L. Picornell-Gelabert, P. Moffa-Sánchez, Y. Llergo, A. Garcia, M. Mus-Amezquita, S. García Álvarez & M. Calvo Trías 2018. 'The onset of islandscapes in the Balearic Islands. A study-case of Addaia (northern Minorca, Spain)', *Palaeogeography, Palaeoclimatology, Palaeoecology* 498, 9–23. https://doi.org/10.1016/j.palaeo.2018.02.015

*Sessa, K. 2019. 'The new environmental fall of Rome. A methodological consideration', *Journal of Late Antiquity* 12:1, 211–255. https://doi.org/10.1353/jla.2019.0008

*Sinclair, P., G. Nordquist, F. Herschend & C. Isendahl, eds., 2010. *The urban mind. Cultural and environmental dynamics* (Studies in Global Archaeology, 15), Uppsala.

Stavi, I., G. Ragolsky, R. Shem-Tov, Y. Shlomi, O. Ackermann, H. Rueff & J. Lekach 2018. 'Ancient through mid-twentieth century runoff harvesting agriculture in the hyper-arid Arava valley of Israel', *CATENA* 162, 80–87. https://doi.org/10.1016/j.catena.2017.11.027

*Stephens, L., D. Fuller, N. Boivin, T. Rick, N. Gauthier, A. Kay, B. Marwick, C.G. Armstrong, C.M. Barton, T. Denham, K. Douglass, J. Driver, L. Janz, P. Roberts, J.D. Rogers, H. Thakar, M. Altaweel, A.L. Johnson, M.M. Sampietro Vattuone, M. Aldenderfer, S. Archila, G. Artioli, M.T. Bale, T. Beach, F. Borrell,

T. Braje, P.I. Buckland, N.G. Jiménez Cano, J.M. Capriles, A. Diez Castillo, Ç. Çilingiroğlu, M. Negus Cleary, J. Conolly, P.R. Coutros, R.A. Covey, M. Cremaschi, A. Crowther, L. Der, S. di Lernia, J.F. Doershuk, W.E. Doolittle, K.J. Edwards, J.M. Erlandson, D. Evans, A. Fairbairn, P. Faulkner, G. Feinman, R. Fernandes, S.M. Fitzpatrick, R. Fyfe, E. Garcea, S. Goldstein, R.C. Goodman, J. Dalpoim Guedes, J. Herrmann, P. Hiscock, P. Hommel, K.A. Horsburgh, C. Hritz, J.W. Ives, A. Junno, J.G. Kahn, B. Kaufman, C. Kearns, T.R. Kidder, F. Lanoë, D. Lawrence, G.-A. Lee, M.J. Levin, H.B. Lindskoug, J.A. López-Sáez, S. Macrae, R. Marchant, J.M. Marston, S. McClure, M.D. McCoy, A.V. Miller, M. Morrison, G. Motuzaite Matuzeviciute, J. Müller, A. Nayak, S. Noerwidi, T.M. Peres, C.E. Peterson, L. Proctor, A.R. Randall, S. Renette, G. Robbins Schug, K. Ryzewski, R. Saini, V. Scheinsohn, P. Schmidt, P. Sebillaud, O. Seitsonen, I.A. Simpson, A. Sołtysiak, R.J. Speakman, R.N. Spengler, M.L. Steffen, M.J. Storozum, K.M. Strickland, J. Thompson, T.L. Thurston, S. Ulm, M.C. Ustunkaya, M.H. Welker, C. West, P.R. Williams, D.K. Wright, N. Wright, M. Zahir, A. Zerboni, E. Beaudoin, S. Munevar Garcia, J. Powell, A. Thornton, J.O. Kaplan, M.-J. Gaillard, K. Klein Goldewijk & E. Ellis 2019. 'Archaeological assessment reveals Earth's early transformation through land use', *Science* 365, 897–902. https://doi.org/10.1126/science.aax1192

*Styring, A.K., M. Charles, F. Fantone, M.M. Hald, A. McMahon, R.H. Meadow, G.K. Nicholls, A.K. Patel, M.C. Pitre, A. Smith, A. Sołtysiak, G. Stein, J.A. Weber, H. Weiss & A. Bogaard 2017. 'Isotope evidence for agricultural extensification reveals how the world's first cities were fed', *Nature Plants* 3, 1–11. https://doi.org/10.1038/nplants.2017.76

Surić, M., A. Columbu, R. Lončarić, P. Bajo, N. Bočić, N. Lončar, R.N. Drysdale & J.C. Hellstrom 2021. 'Holocene hydroclimate changes in continental Croatia recorded in speleothem δ13C and δ18O from Nova Grgosova Cave', *The Holocene* 31, 1401–1416. https://doi.org/10.1177/09596836211019120

Thienemann, M., A. Masi, S. Kusch, L. Sadori, S. John, A. Francke, B. Wagner & J. Rethemeyer 2017. 'Organic geochemical and palynological evidence for Holocene natural and anthropogenic environmental change at Lake Dojran (Macedonia/Greece)', *The Holocene* 27, 1103–1114. https://doi.org/10.1177/0959683616683261

Tinner, W., E. Vescovi, J.F.N. van Leeuwen, D. Colombaroli, P.D. Henne, P. Kaltenrieder, C. Morales-Molino, G. Beffa, B. Gnaegi, W.O. van der Knaap, T. La Mantia & S. Pasta 2016. 'Holocene vegetation and fire history of the mountains of northern Sicily (Italy)', *Vegetation History and Archaeobotany* 25, 499–519. https://doi.org/10.1007/s00334-016-0569-8

*Tuel, A. & E.A.B. Eltahir 2020. 'Why is the Mediterranean a climate change hot spot?,' *Journal of Climate* 33, 5829–5843. https://doi.org/10.1175/JCLI-D-19-0910.1

*United Nations 2015. Transforming our world. The 2030 agenda for sustainable development, Department of Economic and Social Affairs. Sustainable Development. https://sdgs.un.org/2030agenda.

Vacchi, M., K.M. Joyse, R.E. Kopp, N. Marriner, D. Kaniewski & A. Rovere 2021. 'Climate pacing of millennial sea-level change variability in the central and western Mediterranean', *Nature Communication* 12, 4013, 9 pp. https://doi.org/10.1038/s41467-021-24250-1

Van Bommel, D., H.J. Bruins, N. Lazarovitch & J. van der Plicht 2021. 'Effect of dung, ash and runoff water on wheat and barley grain sizes and stable isotope ratios. Experimental studies in ancient desert agriculture (Negev, Israel)', *JAS Reports* 39, 103172, 14 pp. https://doi.org/10.1016/j.jasrep.2021.103172

Van Loo, M. & G. Verstraeten 2021. 'A spatially explicit crop yield model to simulate agricultural productivity for past societies under changing environmental conditions', *Water* 13, 2023, 25 pp. https://doi.org/10.3390/w13152023

Vidal-Cordasco, M. & A. Nuevo-López 2021. 'Resilience and vulnerability to climate change in the Greek Dark Ages', *JAnthArch* 61, 101239, 14 pp. https://doi.org/10.1016/j.jaa.2020.101239

Vignola, C., J. Bonetto, G. Furlan, M. Mazza, C. Nicosia, E. Russo Ermolli & L. Sadori 2021. 'At the origins of Pompeii. The plant landscape of the Sarno river floodplain from the first millennium BC to the AD 79 eruption', *Vegetation History and Archaeobotany* 31, 171–186. https://doi.org/10.1007/s00334-021-00847-w

Walsh, K., J.-F. Berger, C.N. Roberts, B. Vanniere, M. Ghilardi, A.G. Brown, J. Woodbridge, L. Lespez, J. Estrany, A. Glais, A. Palmisano, M. Finné & G. Verstraeten 2019. 'Holocene demographic fluctuations, climate and erosion in the Mediterranean. A meta data-analysis', *The Holocene* 29, 864–885. https://doi.org/10.1177/0959683619826637

**Web of Science Core Collection* 2021. https://www.webofscience.com/wos/woscc/basic-search

Weiberg, E. & M. Finné 2018. 'Resilience and persistence of ancient societies in the face of climate change. A case study from Late Bronze Age Peloponnese', *WorldArch* 50, 584–602. https://doi.org/10.1080/00438243.2018.1515035

Weiberg, E., A. Bevan, K. Kouli, M. Katsianis, J. Woodbridge, A. Bonnier, M. Engel, M. Finné, R. Fyfe, Y. Maniatis, A. Palmisano, S. Panajiotidis, C.N. Roberts & S. Shennan 2019a. 'Long-term trends of land use and demography in Greece. A comparative study', *The Holocene* 29, 742–760. https://doi.org/10.1177/0959683619826641

Weiberg, E., R.E. Hughes, M. Finné, A. Bonnier & J.O. Kaplan 2019b. 'Mediterranean land use systems from prehistory to antiquity. A case study from Peloponnese (Greece)', *Journal of Land Use Science* 14:1, 1–20. https://doi.org/10.1080/1747423X.2019.1639836

Weiberg, E., A. Bonnier & M. Finné 2021. 'Land use, climate change and "boom-bust" sequences in agricultural landscapes. Interdisciplinary perspectives from the Peloponnese (Greece)', *JAnthArch* 63, 101319, 12 pp. https://doi.org/10.1016/j.jaa.2021.101319

Weinelt, M., J. Kneisel, J. Schirrmacher, M. Hinz & A. Ribeiro 2021. 'Potential responses and resilience of Late Chalcolithic and Early Bronze Age societies to Mid-to Late Holocene climate change on the southern Iberian peninsula', *Environmental Research Letters* 16:5, 055007, 19 pp. https://doi.org/10.1088/1748-9326/abd8a8

Werner, V., K. Baika, A. Tzigounaki, K. Reicherter, I. Papanikolaou, K. Emde, P. Fischer & A. Vött 2019. 'Extreme wave events recorded in sedimentary archives of the Geropotamos river (north-central Crete, Greece)', *Zeitschrift für Geomorphologie* 62:2, 63–100. https://doi.org/10.1127/zfg_suppl/2019/0602

*Whitelaw, T. 2019. 'Feeding Knossos. Exploring economic and logistical implications of urbanism on prehistoric Crete', in *Country in the city. Agricultural functions of Protohistoric urban settlements (Aegean and Western Mediterranean)*, eds. D. Garcia, R. Orgeolet, M. Pomadere & J. Zurbach, Oxford, 88–121. https://doi.org/10.2307/j.ctvr00x98.9

Whitford, B.R. 2019. 'Characterizing the cultural evolutionary process from eco-cultural niche models. Niche construction during the Neolithic of the Struma river valley (c. 6200–4900 BC)', *Archaeological and Anthropological Science* 11, 2181–2200. https://doi.org/10.1007/s12520-018-0667-x

Woodbridge, J., C.N. Roberts, A. Palmisano, A. Bevan, S. Shennan, R. Fyfe, W.J. Eastwood, A. Izdebski, C. Çakırlar, H. Woldring, N. Broothaerts, D. Kaniewski, M. Finné & I. Labuhn 2019. 'Pollen-inferred regional vegetation patterns and demographic change in southern Anatolia through the Holocene', *The Holocene* 29, 728–741. https://doi.org/10.1177/0959683619826635

*Xoplaki, E., D. Fleitmann, J. Luterbacher, S. Wagner, J.F. Haldon, E. Zorita, I. Telelis, A. Toreti & A. Izdebski 2016. 'The medieval climate anomaly and Byzantium. A review of the evidence on climatic fluctuations, economic performance and societal change', *Quaternary Science Reviews* 136, 229–252. https://doi.org/10.1016/j.quascirev.2015.10.004

Yanes, Y. & J. Fernández-Lopez-de-Pablo 2017. 'Calibration of the stable isotope composition and body size of the arid-dwelling land snail *Sphincterochila candidissima*, a climatic archive abundant in Mediterranean archaeological deposits', *The Holocene* 27, 890–899. https://doi.org/10.1177/0959683616675943

Zanchetta, G., M. Bini, M.A. Di Vito, R. Sulpizio & L. Sadori 2019. 'Tephrostratigraphy of paleoclimatic archives in central Mediterranean during the Bronze Age', *Quaternary International* 499:B, 186–194. https://doi.org/10.1016/j.quaint.2018.06.012

Appendix: keywords in categories and quantity

Details of the keywords according to CATEGORY (upper case), *Subcategory* (*Italics*) and Thematic groups (only found under the subcategory Topic), with quantities specified within parenthesis. The number of separate keywords counted after standardization of variabilities due to spelling, singular/plural use or the use of abbreviations.

GEOGRAPHY (255)
Mediterranean (43): Mediterranean (21); western Mediterranean (7); eastern Mediterranean (6); Mediterranean Sea (4); Mediterranean Basin (2); central-west Mediterranean; north-east Mediterranean; south-east Mediterranean
Balkans (44): Greece (13); Crete (5); Peloponnese (5); Croatia (3); Balkans (2); north-east Greece (2); south-east Balkans (2); Aegean; Akrotiri; Ancient Greece; Argosaronic gulf; Cyclades; Early Iron Age Greece; Gulf of Corinth; Lake Dojran; Late Bronze Age Greece; northern Greece; Phaistos; Bulgaria
Central Mediterranean (41): Po Plain (3); Corsica (2); Northern Italy (2); southern Italy (2); Tuscany (2); Vesuvius (2); Alps; Apulia; Basilicata; central Adriatic coast; central Italy; Cilento; Eastern Sardinia; France; Gaul; Ggantija and Santa Verna temples; Istrian peninsula; Italy; Malta; Middle Rhone valley; Northern Apennines; north-west Italy; Pompeii; Puglia; Rome; Sila uplands; Sinis Peninsula; south Italy; southern Alps; southern France; Tharros; Tiber River; Tyrrhenian Calabria coast; Tyrrhenian Sea
Near East (37): Levant (6); Near East (5); southern Levant (5); Middle East (3); south-west Asia (3); Dead Sea (2); Sea of Galilee (2); Atar Haroa; Ayn Abu Nukhayla; Fertile Crescent; Iran; Israel; Jordan; Mesopotamia; northern Levant (coastal Syria); Petra; Syria; Tel Megiddo
Iberia (32): Iberian Peninsula (8); Spain (5); Iberia (2); north-east Iberia (2); Balearic Sea; Central Iberia; Cova de Can Sadurni; Cova de la Guineu; Ebro Basin; Huelva Estuary; Lake Medina; Mallorca (Balearic Islands); Mediterranean Iberia; Portugal; Pyrenees; southern Iberia; south-west Iberia; Spanish Pyrenees; south-west Spain
Anatolia (27): Cappadocia (3); Turkey (3); Anatolia (2); Arslantepe (2); western Anatolia (2); Bor Plain; Catalhoyuk; Central Anatolian Volcanic Province (CAVP); Delice Valley; Eastern Anatolia; Ephesos; Istanbul-Turkey; Konya; Kultepe; Lake Tuzla; Phrygia; Rough Cilicia; south-west Anatolia; Ulucak Hoyuk; Western Turkey
Southern Mediterranean (23): North Africa (3); Egypt (2); Gredos range (2); Morocco (2); Tunisia (2); Algeria; Fayum; Gulf of Gabes; Haua Fteah; Holocene North Africa; Libya; Lower Egypt; Maghreb; Mediterranean Africa; Middle Atlas; north-west Africa; Utica
Other (8): western Europe (3); eastern Europe (2); Europe; European and Mediterranean regions; Okmok
DISCIPLINE (168)
Intermediate (71): geoarchaeology (15); palynology (14); archaeobotany (10); palaeoecology (9); archaeozoology (5); anthracology (4); environmental archaeology (3); palaeobotany (2); palaeoecology and land-use history (2); archaeopalynology; historical ecology; human ecology; island ecology; local ecology; pedoanthracology; socioecology
Natural science (50): geochemistry (6); palaeogeography (6); sedimentology (5); palaeoclimatology (7); geomorphology (4); coastal geomorphology (3); micromorphology (3); hydrology (2); palaeolimnology (2); alluvial geomorphology; biogeography; geology; geophysics; historical biogeography; hydrogeology; micropalaeontology; natural sciences; palaeohydrology; palaeopedology; soil micromorphology; volcanology
Humanities and Social sciences (47): archaeology (21); landscape archaeology (9); demography (5); history (3); prehistoric archaeology (2); anthropology; archaeo-demography; California archaeology; Greek & Roman archaeology; maritime archaeology; palaeodemography; settlement archaeology
CHRONOLOGY (202)
Holocene (76): Holocene (52); Late Holocene (12); Mid-Holocene (6); Mid- to Late Holocene (2); Early Holocene; Mediterranean Mid-Holocene; Middle and Early Holocene; second half Holocene
Bronze Age (59): Bronze Age (23); Chalcolithic (7); Early Bronze Age (6); Late Bronze Age (3); Middle Bronze Age (3); Minoan (2); Amorites; Argar period; Argaric culture; Copper Age; EB-MB transition; Eneolithic/Bronze Age; First Intermediate Period; Hatti; Middle-Recent Bronze Age; Minoan civilization; Mycenaean influence; Old Kingdom; Sea Peoples; Subapennine culture; Terramare culture
Neolithic (30): Neolithic (21); Early Neolithic (4); Pre-Pottery Neolithic (2); Fifth millennium cal BC; Late Neolithic; Middle Neolithic
Historical (20): Iron Age (5); Classical Antiquity (2); Roman period (2); Antiquity and Late Antiquity; Archaic and Classical periods; Graeco-Roman period; Historic period; last millennia; last three millennia; (pre-)Roman age; protohistory; Punic period; Roman Age; Roman and Byzantine times
Other (17): Aegean prehistory (3); prehistory (3); Anthropocene (2); Quaternary (2); Late glacial (2); Apulian prehistory; Epipalaeolithic; Late Pleistocene-Holocene; Pleistocene; Upper Quaternary
METHOD (119)
Environment (27): pollen analyses (8); carbon isotope analysis (5); wood charcoal analysis (4); charcoal analysis (4); anthraco-typology; isotope analysis; pollen identification; seed and fruit analysis; sequential isotope analysis; stable isotope geochemistry
Archaeology (17): geographic information systems (GIS) (4); archaeological site survey (2); radiocarbon summed probability distribution (2); aoristic weights; archaeological interpretations; least-cost path analysis; point pattern analysis; site count; summed calibrated date distributions; summed probability densities; survey; visibility analysis
Modelling (17): modelling (3); agent-based model (2); agro-ecosystem modelling; agrosystem modelling; computational modelling; crop modelling; eco-cultural niche modelling; geographical information modelling; geomorphic modelling; irrigation modelling; land use modelling; palaeoclimate modelling; spatially explicit hydrological model; surface process modelling
General (16): multiproxy (2); boreholes; change analysis; classification; coring; data analysis; downscaling; fuzzy; high-performance computing; high-resolution proxy records; multi-proxy approach; multi-proxy records; proxy synthesis; statistical downscaling; stratigraphy
Dating (16): radiocarbon dating (8); tephrochronology (2); uranium series dating (2); Optically stimulated luminescence (OSL); sclerochronology; (U-Th)/He; Zircon double-dating
Computational (9): cluster analysis (2); Canonical discriminant analysis (CDA); D-Infinity algorithm; geometric morphometrics; Principal Component Analysis (PCA); XylArch; cumulative probability functions of C-14 ages; non-metric multidimensional scaling (nMDS)

Other (17): tephrostratigraphy (3); magnetic susceptibility (2); organic residue analyses; geomorphometry; magnetostratigraphy; thin section micromorphology; clay mineralogy; morphostratigraphy; side scan sonar; X-ray fluorescence (XRF); XRF analysis; bathymetry; sub-bottom profiler; last growth episode
ARCHIVE (31)
Sediments (23): lake sediment (4); speleothem (4); stalagmite (3); lacustrine sediment (2); clastic cave sediments; geoarchive; ice core; lake fills; lake record; laminated sediments; sediment cores; speleothem data; varved lake sediments; varves
Other (8): ancient shipwreck; archaeological data; archaeological mound; archaeological sediment; historical maps; land snails; literary sources; Unio
PROXY (126)
Fossil (97): pollen (32); charcoal (5); biomarkers (3); macrofossils (3); micro-charcoal (3); soil (3); diatoms (2); fossil pollen (2); n-alkanes (2); non-Pollen Palynomorphs (NPP) (2); ostracods (2); phytolith (2); aeolian dust; alkenone; ancient DNA; anhydrosugars; anthropogenic indicators; archaeological leaves; biological indicators; Coleoptera; dark-filled pollen; dung fungi; fossil records; fungal spores; galactosan; glycerol dialkyl glycerol tetraether (GDGT); glomalin-related soil protein; human remains; human settlement patterns; Levoglucosan; lipid biomarker; long-chain alkane; macrocharcoal; macrophytes; mannosan; marine sand; microfossils; Minoan tephra; planktonic foraminifera; plant macrofossils; pollen records; pumices; seeds; sheep morphotypes; soot; spherulite; tooth enamel; wood charcoal
Isotopes (23): stable isotopes (8); carbon isotopes ($\delta^{13}C$) (4); hydrogen isotopes (δD) (2); oxygen isotopes ($\delta^{18}O$) (2); stable isotope compositions (2); leaf wax carbon isotope; leaf wax hydrogen isotope; nitrogen isotopes ($\delta^{15}N$); stable isotope ratios; strontium isotopes
Other (6): archaeological site (4); demographic proxies; magnetic properties
TOPIC (630)
Climate (138)
General (69): climate change/s (30); palaeoclimate (24); climate (8); climate dynamics (2); climate variability (2); Mid Holocene climate change; past climate change; historical climate change
Types (31): hydroclimate (3); precipitation (2); seasonality (2); rainfall; humidity; temperature; rainfall variability; seasonal climate; arid desert climate; aridification; hydroclimate changes; hydroclimate variability; Holocene hydroclimate; effective rain; monsoons; seasonal; sea surface temperature (SST); snow
Events/Periods (29): 4.2 ka BP climate event (7); rapid climate change (5); 8.2 ka BP climate event (4); 3.2 ka BP climate event (2); drought (2); 8.2 and 7.7/7.1 ka BP climate events; 9.2 ka BP climate event; aridity events; climate events; Late Antique Little Ice Age; Younger Dryas; climatic events; Roman Climate Optimum; Roman Warm Time
Mechanisms (9): North Atlantic Oscillation (NAO) (2); climate forcing; atmospheric circulation; North Sea Caspian Pattern (NCP); ocean circulations; solar activity; glacier fluctuations; atmospheric CO_2
Environment (64)
General (20): palaeoenvironment (9); palaeoenvironmental reconstructions (4); environment; environmental change; environmental management; environmental stress; Mediterranean palaeoenvironment; palaeoenvironmental changes; palaeogeographical evolution

Types (25): dune (2); lake (2); Mediterranean island (2); mountain (2); volcano (2); wetland (2); alpine wetland; boulder; islands; karstic cave; lagoon; maritime; marshland ecosystems; mound; mountain belts; mountain environments; salt lake; subalpine environment; wet habitats
Coastal environments (19): Sea-level change (2); coastal change; coastal evolution; coastal floodplains; coastal lagoon; coastal stratigraphy; delta progradation; deltaic evolution; estuary; Holocenic sea level rise; littoral drift; millennial scale transgressive-regressive cycles; regression; ria infilling; sea level changes; sea-level; shoreline; transgression
Hydrology and soil (52)
Soil (28): anthropogenic soils; argillic; biocrusts; brown/red Mediterranean soils; calcification; clast pavements; degree of soil development; grain size variations; Holocene geomorphodynamic activity; loess; nutrients; palaeosoil; peat initiation; pedosedimentary processes; rubefication; ruin soil; salinization; sediment connectivity; sediment texture; soil chronosequence; soil depletion; soil fertility; soil thickness; surface soil; synlithogenic pedogenesis; tempestite; turbidites; vesicular layer
Hydrology (15): runoff coefficient (2); aquatic productivity; aquifers; calcareous tufa; groundwater; hillslope vs. channel hydrology; hydrological connectivity; hydrological cycle; rainfall:runoff ratio; rainfall-runoff analysis; runoff; spatio-temporal distribution of mires; stop-and-go transport; transmission loss
Fluvial processes (9): alluvial phases; alluvial-coastal plain; fluvial metamorphosis; fluvial system; fluvial wetland; fluvioglacial and fluvial terraces; Late-Holocene river migration; Po and Dora Baltea rivers evolution; river avulsions
Land cover (61)
General (36): vegetation dynamics (9); vegetation (6); land cover (5); vegetation history (3); biodiversity (2); ecological succession (2); palaeovegetation; palaeo-vegetation; past vegetation; potential natural vegetation; stomata; vegetation and climate change; vegetation changes; vegetation cover change; vegetation dynamic synthesis
Taxa (20): Fagus sylvatica (2); Pinus halepensis Miller; Abies alba; Abies nebrodensis; Alnus; Brassicaceae; Buxus sempervirens; C_4 vegetation; Characeae; deciduous Quercus; Erica scoparia and E. arborea; Laurus nobilis; oak distribution; palm leaves; Pinus halepensis; Pinus laricio; Posidonia oceanica; Quercus ilex forests; Astragalus
Forest (5): deforestation (2); forest clearance; forest disruption; forest history
Landscape (61)
General (16): landscape (4); landscape changes (2); landscape ecology (2); site formation processes (2); desertification; landscape stability; landscape taphonomy; landscape transformations; landscape use; Roman landscape
Hazard (19): coseismic uplift; deluge; earthquakes; eruption impact; explosive eruptions; extreme wave events; flood; flood chronicle; flood events; natural disaster; palaeoflooding; palaeotsunami; Plinian eruption; rainstorm and floods; seismicity; Southern Italian volcanoes; tectonic events; tsunami; volcanoclastic mass flow
Erosion (15): erosion (4); soil erosion (3); badland; incised valley systems; land erosion; mass movements; piping; stabling areas; surface erosion; weathering conditions
Fire (11): fire (3); fire history (2); palaeofire (2); biomass burning; fire ecology; fire practices; fire regimes

Land use (115)
General (19): land use (15); land use change (2); land use history (2)
Agriculture (33): agriculture (5); crop yield (2); cultivation (2); domestication (2); early agriculture (2); farming (2); subsistence (2); agricultural revolution; agricultural sustainability; agro-pastoral farming; alpine farming; ancient agriculture; ancient desert agriculture; ancient farming; ancient runoff farming; cultivation terraces; irrigation; manuring experiments; Nile flow; prehistoric agriculture; runoff/floodwater irrigation; subsistence strategies; terraces
Crops (21): olive (2); Vitis (2); Flax cultivation; fruit growing; fruits; Hordeum distichum; Linum usitatissimum L.; Olea europaea L.; Olive grove; olive growing; olive oil; olive orchards; olive press; olive tree cultivation; Roman vineyards; small grain crops; tree crops; Triticum aestivum; wheat
Resource exploitation (17): ancient water management (2); ancient water harvesting system; avian exploitation; birds; ecosystem services; forest resources; fuel management; fuel wood; groundwater management; lead concentration; mining activities; plant use; plant; runoff water harvesting; trade; wood management
Husbandry (16): pastoralism (3); altitudinal mobility; animal economy; animal husbandry; browsing; herding strategies; livestock management; overgrazing; pastoral nomads; pasture; pasture indicators; secondary products; sheep and goats; transhumance
Food (9): food shortages (2); crop-processing; dairying; famine; food plants; foodways and climate change; palaeodiet; storage
Dynamics (51)
Human (44): human impacts (23); human-environment interaction (6); anthropisation (3); anthropogenic impact (3); human occupancy (2); anthropogenic dynamics; human activities; human inhabitation; human-environment-climate interaction; social-ecological system; socio-ecosystem; socioenvironmental dynamics
Climate (7): climate adaptation; climate and society; climate change impact; climate impact; climate versus human change; climate-environment-society interactions; past climate impacts

Theory and concepts (57)
General (36): interdisciplinarity (3); abandonment (2); culture change (2); Late Bronze Age crisis (2); causal impact; collapse; consilience; crisis; cultural evolution; disaster; global change; historical maximalism; holistic approach; human carrying capacity; identity; interdisciplinary collaboration; mobility; niche construction; resolution; science oversimplification; sedentism; shape; size; social organization; social transformation-abrupt cultural change; societal change; socio-economic aspects; socio-political structures; spatially explicit; state formation; urban
Resilience theory (21): resilience (8); scale (2); adaptive cycle; complexity; emergence; human adaptation; human resilience; legacy effects; mitigation; sustainability; sustainable land use; sustainable use; vulnerability
Archaeology and history (31)
General (22): ancient societies (2); ancient Ostia harbour; architecture; cord impressions; geomythology; Greek and Roman colonization; myth; mythology; Neolithic dispersal; Neolithic transition; Neolithisation; pottery production; production intensification; Punic harbour; red slip ware; Roman baths; roulette decor; shell middens; stone tool; tabular scraper; tell
Demography (9): demographic dynamics; past population density; population dynamics; population genetics; population proxy; residential mobility; settlement; settlement patterns; settlement strategies

Supplemental information

Spreadsheet outlining complete records from the *WoS* search pertaining to the 280 articles.

RIS-file (and other formats) with references for the 280 articles, for import into a reference manager system. Available at https://doi.org/10.30549/opathrom-15-07.