# The Emergence of Interdisciplinary Environmental History

## Collaborative Approaches to the Late Holocene

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**History as a discipline** finds itself in a transitional situation. On the one hand, new kinds of evidence are available, but since these did not form part of their training, many historians feel uncomfortable working with data derived from palynology, dendrology, glaciology, osteology, archaeogenetics, and so on. On the other hand, the current global crisis, including unprecedented climate change, ecosystem disturbance, and the (not unrelated) emergence of highly transmissible pathogenic diseases, has caused us to look more generally to the past for parallels, meaning, and guidance. Practitioners from other disciplines—notably medical professionals, environmental scientists, and economists—have taken over this task, relaying "historical lessons" to the public. Historians are too often little involved in the debates about current challenges and the future of the planet that ensue, debates that capture public attention and help to shape our future.

* This article was first published in French as "L'émergence d'une histoire environnementale interdisciplinaire. Une approche conjointe de l'Holocène tardif," *Annales HSS* 77, no. 1 (2022): 11–58. It is an outcome of the conference organized by the Climate Change and History Research Initiative at Princeton University in May 2017. Joseph G. Manning, Alexander R. Stine, and Francis Ludlow would like to thank the United States National Science Foundation (NSF) for its generous support (grant no. 1824770 CNH-L, "Volcanism, Hydrology, and Social Conflict: Lessons from Hellenistic and Roman-Era Egypt and Mesopotamia"). Francis Ludlow thanks the Harvard University Center for the Environment for the Ziff Environmental grant and the Initiative for the Science of the Human Past at Harvard for its generous support. Piotr Guzowski thanks the Polish Ministry of Science and Higher Education's National Program for the Development of



*Annales HSS (English Edition)*, 10.1017/ahsse.2022.21

To address this situation, historians must engage with the new evidence and new disciplinary and theoretical perspectives on the past that have emerged in recent decades. Moreover, they must defend the relevance of what, from an evolutionary perspective, would be called the recent human past—stretching from antiquity to the Industrial Revolution—to the big questions that loom large in the public imagination. The present authors, including eight historians and eight natural scientists, wish to support these efforts by discussing the ways in which historians can dialogue with the natural sciences. For reasons of space, we will focus here on earth sciences, the branch of the natural sciences that has long had the most extensive interactions with history, while acknowledging the many other natural scientific fields that exert an influence, and sometimes an important one, on the discipline, such as ancient DNA research (archaeogenetics) and cognitive science.[1]

From a geological perspective, and according to the timescales employed in the earth sciences, nearly all historians work on the Late Holocene—the last three thousand years, more or less. The onset of this era coincides with the rise of "classical civilizations" at both ends of Eurasia and in Mesoamerica, the Indus Valley, and elsewhere, which in turn initiated socioeconomic and political processes that have contributed immensely to our technological achievements but also to our present predicaments, from the climate crisis to the mass extinction of species, and to the advent of the Anthropocene.[2] The Late Holocene, surprisingly stable in its climatic variability compared to the Early Holocene, earlier glacial and interglacial periods, or indeed the twentieth century CE, is the period for which we are best equipped to study the human past. In addition to the material record from the dawn of human evolution onward, traditionally the domain of archaeology, and the palaeoenvironmental data collected from nature's "archives" and studied by natural scientists, there is abundant written evidence that generally increases in volume and quality as we near the present. This textual evidence, which opens up unique research opportunities and the ability to more comprehensively reconstruct the human past, means that the Late Holocene may be considered the "age of

the Humanities for its support between 2016 and 2019. Alexander R. Stine also received two grants from the NSF (AGS-1903674 and ICER-1824770). Elena Xoplaki is grateful to the Academy of Athens and the Greek "National Network on Climate Change and Its Impacts" (project 200/937), as well as the German Ministry of Education and Research projects NUKLEUS and ClimXtreme, and the German Academic Exchange Service (DAAD) project EM-MHeatwaves. The authors thank Niklas Luther of Justus Liebig University Giessen for the analysis and presentation of figures 1 and 2.

1. On ancient DNA, see, for example, Carlos Eduardo G. Amorim et al., "Understanding 6th-Century Barbarian Social Organization and Migration through Paleogenomics," *Nature Communications* 9, no. 1 (2018): https://doi.org/10.1038/s41467-018-06024-4. On cognitive science, see in particular Rob Boddice and Daniel Lord Smail, "Neurohistory," in *Debating New Approaches to History*, ed. Marek Tamm and Peter Burke (London: Bloomsbury Academic, 2018), 313–18.

2. On the advent of the Anthropocene and its use as a concept by historians, see the thematic dossier "Anthropocene," *Annales HSS (English Edition)* 72, no. 2 (2017): 161–272.

historians." This era is studied across hundreds of history departments on all continents, where historians have spent decades, and in some cases centuries, working to explain the dynamics of complex Late Holocene societies. There is no question that these historians have much to contribute to the emerging interdisciplinary dialogue on humanity's place in the planet's longer history.

While the palaeosciences join this dialogue with their own questions, they aim neither to supersede history nor to assume the preeminent interpretive role in reconstructing the human past. At the same time, to bring in new sources is also to introduce new uncertainties. Though incertitude has been the daily bread of historians for centuries, engaging with new methodologies, in particular through the use of data originating in the natural sciences, forces the discipline to confront these new uncertainties. They often relate to the dating, spatial relevance, and indeed the precision of the scientific data; in other words, how reliable they are in doing what historians want them to do. This is both a methodological challenge and an opportunity, as by combining a wider range of sources, each with its own (independent) uncertainties, we may eventually increase our confidence in the visions of the past that we present and reduce the documentary constraints that historians traditionally face.

A change in mindset regarding what sources can be used to study the human past has already been underway for more than a decade. During that time, palaeoscientists have started publishing data relevant to Late Holocene history and inevitably proposing novel environmental explanations for major historical events and processes.[3] In this they have often sought to demonstrate the broader utility of their data via their application to questions of human history, but have also been motivated by a genuine desire to understand how past societies responded to environmental changes, being perhaps more keenly aware than others of the perilous trajectory of future climatic change.[4] Some historians have responded by engaging with a range of natural scientific evidence and the arguments based upon it.[5] If newly produced scientific data are, however, to become

3. A recent well-known example is Ulf Büntgen et al., "Cooling and Societal Change during the Late Antique Little Ice Age from 536 to around 660 A. D.," *Nature Geoscience* 9, no. 3 (2016): 231–36.

4. Though there have been earlier phases of such interest within the discipline of history, in particular in the context of the Annales school. See, for instance, "History and Climate: Interdisciplinary Explorations," special issue, *Journal of Interdisciplinary History* 10, no. 4 (1980). The contemporary phase addressed in the present article is distinguished by huge advances in the scope, accuracy, and precision of the data now provided by the natural sciences, but also by access to historical archives on an unprecedented scale thanks to digitization and new methods of content analysis.

5. Recent examples include Nicholas P. Dunning, Timothy P. Beach, and Sheryl Luzzadder-Beach, "Kax and Kol: Collapse and Resilience in Lowland Maya Civilization," *Proceedings of the National Academy of Sciences* 109, no. 10 (2012): 3652–57; Steven Hartman et al., "Medieval Iceland, Greenland, and the New Human Condition: A Case Study in Integrated Environmental Humanities," *Global and Planetary Change* 156 (2017): 123–39; Amorim et al. "Understanding 6th-Century Barbarian Social Organization"; Joseph R. McConnell et al., "Lead Pollution Recorded in Greenland Ice Indicates

widely accepted as legitimate sources within the discipline of history, on par with the information provided by textual evidence and the remains of material culture, we must learn how to handle them properly, identifying their strengths but also probing their limitations.

To do this, historians must search out and advance theoretical frameworks and research-design models that are inclusive of natural scientific data. In the context of the earth sciences, such frameworks have been offered by environmental historians, often informed by historical geographers, historical and human ecologists, economic historians, and others. Environmental history most clearly originates in the environmental movements of the 1960s and is particularly strong in the United States.[6] However, it is arguably on the European side of the Atlantic that interdisciplinarity has become an integral part of environmental history research, shaping the field into an often surprising, polymorphous alliance of natural scientists and historians. The work produced by these collaborations reflects several different theories of human-environmental relations. Many are adapted from ecology, but there are also models drawn from history, such as the climate impacts model developed by Christian Pfister and other climate historians, which is inspired by economic history and sees natural forces as external "shapers" of human experience, or that proposed by Richard C. Hoffmann and Verena Winiwarter, which focuses more on the continuous feedbacks between natural processes and human action.[7] We will refer to several of these models and their practical implementations throughout this paper, before considering them from a rhetorical and metanarrative point of view in the conclusion. It should also be stressed that the interdisciplinary environmental history we discuss here tends per se to be positivistic and materialistic in both its objectives and its epistemology. Its focus is on reconstructing past biological or geological states and phenomena and relating them to societal processes, which necessitates the establishment of robust chronologies and precise reconstructions.

The present article will begin by outlining some of the intricacies of the palaeoenvironmental evidence with which historians can engage. It also discusses the key issue of the spatiotemporal scales on which the emerging field of interdisciplinary environmental history needs to flexibly operate. It then presents several

European Emissions Tracked Plagues, Wars, and Imperial Expansion during Antiquity," *Proceedings of the National Academy of Sciences* 115, no. 22 (2018): 5726–31; Dan Penny et al., "Geoarchaeological Evidence from Angkor, Cambodia, Reveals a Gradual Decline Rather than a Catastrophic 15th-Century Collapse," *Proceedings of the National Academy of Sciences* 116, no. 11 (2019): 4871–76.

6. Grégory Quenet, *Qu'est-ce que l'histoire environnementale?* (Seyssel: Champ Vallon, 2014).

7. One of the most classical applications of the climate history model is Christian Pfister and Rudolf Brázdil, "Social Vulnerability to Climate in the 'Little Ice Age': An Example from Central Europe in the Early 1770s," *Climate of the Past* 2, no. 2 (2006): 115–29. For the "feedback" approach, see for instance the introductions to Richard C. Hoffmann, *An Environmental History of Medieval Europe* (Cambridge: Cambridge University Press, 2014); and Verena Winiwarter and Martin Knoll, *Umweltgeschichte. Eine Einführung* (Cologne: Böhlau, 2007).



https://doi.org/10.1017/ahsse.2022.21 Published online by Cambridge University Press

case studies: practical examples of research that attempts to develop historical narratives using both textual and natural scientific evidence. From simply gathering and discussing the diverse evidence to carrying out intricate literary or quantitative analyses, the potential approaches are manifold—as are their strengths and weaknesses. Finally, our concluding section considers the master narratives that dominate the field of interdisciplinary environmental history and presents some recommendations for future studies.

## Palaeoenvironmental Data from a Historian's Perspective

The natural sciences are highly diverse and pluralistic. There is no single palaeoscience (a discipline or branch of the natural sciences that would deal with the past *in toto*), nor is there a single interdisciplinary environmental history. Most historians who interact with the earth sciences either specialize in working with a single branch, gradually acquiring the expertise to critically engage with the evidence it produces (these are "interdisciplinary historians" in a strict sense), or they draw on specific studies relevant to a particular historical inquiry, which they use to place their research questions in a broader context (we might call these scholars "open-minded" historians, and say they have the habit of "reading widely"). Few members of either group are aware of just how diverse, rich, or heterogeneous the world of the earth sciences—and, by extension, the palaeosciences—actually is.

Of the methodologies at the interface of history and the natural sciences, the study of past climate change has probably the longest research tradition.[8] In the context of modern historiography, climate change is a general notion that translates into a wide range of processes and phenomena occurring at different spatial and temporal scales. These can involve extreme rainfall events taking place on short timescales such as hours or days, droughts that persist for weeks or even years, or abnormal weather conditions over a full season or series of consecutive years (such as a decade of weaker monsoons in tropical zones following a strong volcanic eruption). They also include longer-term trends in climate conditions over a given area, occurring at multi-decadal or even centennial scales (for instance, drying or cooling trends caused by external forcing or internal variations of the climate system). The variety of weather and climate phenomena makes clear that no easy generalization can be made about climate's role in history. Depending on the type of climate change we are concerned with, its interaction with any particular society (and related ecosystems, understood together as a holistic social-ecological system) will differ according to what weather or climate phenomena actually occurred—or, to be more precise, what our *interpretation* of the palaeoclimatic data suggests occurred. And this, of course, comes on top of the many intricacies of the specific

8. Starting in mature form with the works of Emmanuel Le Roy Ladurie, notably "Histoire et Climat," *Annales ESC* 14, no. 1 (1959): 3–34.



https://doi.org/10.1017/ahsse.2022.21 Published online by Cambridge University Press

cultural, economic, and political systems which conditioned how that society would or could respond to said climate change.[9]

Past climate variability has left traces in both human and natural records, which can take the form of lake and marine sediments, peat deposits, speleothems in caves, living and dead trees, ice layers, and so on. When properly interrogated, each of these archives can return a wide range of proxies, that is, measured physical or chemical indicators that approximate past environmental conditions, though they do not reflect any parameters in a direct, one-to-one relationship. As the field of palaeoclimatology has developed and matured, the proxies used have become increasingly numerous and diverse. Since these archives were created through a variety of (natural) environmental processes, they require different methods of extraction and analysis. To make sense of an archive and establish a proxy, one may need to recognize the morphology of plant parts or animals, measure inorganic compounds and element concentrations, or undertake isotopic measurements of organic and inorganic materials. Many different scientific fields are involved, each requiring a high degree of specialization.

Climate reconstructions based on documentary and natural proxies contain several uncertainties, though this does not undermine their reliability. An important aspect of working with these uncertainties is proxy calibration: as we cannot measure past climate directly, we only measure extant organic and inorganic matter that result from complex processes influenced by past climate variables or other meteorological phenomena. We calibrate the proxy data—collected in the field and measured and analyzed in the laboratory—by comparing them with modern observations from meteorological instruments, usually encompassing the nineteenth and twentieth centuries. This enables us to make temperature or precipitation estimates for specific parts of a given year. In some cases, the proxies reflect a combination of temperature and precipitation and can provide more generalized information about winter conditions or droughts. Even more significant is chronological uncertainty, which will be discussed below. The overall combination of intrinsic dating uncertainty and the margins of error involved in the process of palaeoclimatic reconstruction (proxy calibration) ultimately contributes to a kind of composite or multifarious uncertainty, which a historian using this data must navigate.

Natural scientific studies of past landscapes—palaeoecology—share many challenges with palaeoclimatology, especially when it comes to chronology. Palaeoecology or palaeoenvironmental science also employs highly heterogeneous approaches to reconstruct the past. In the majority of cases, palaeoenvironmental researchers work on sediment cores, that is, long columns of organic and inorganic matter (or "mud") extracted from locations such as lake beds or peat bogs that favor its accumulation layer after layer, and which ensure the preservation of organic material over long periods. These cores can be analyzed using various

9. Dagomar Degroot et al., "Towards a Rigorous Understanding of Societal Responses to Climate Change," *Nature* 591, no. 7851 (2021): 539–50.



https://doi.org/10.1017/ahsse.2022.21 Published online by Cambridge University Press

methods, beginning with sediment geochemistry to establish local erosion patterns and the physical-biological processes behind the production and accumulation of the sediments. Major shifts in such parameters may reflect important transformations of a local ecosystem or even an entire landscape at particular moments in the past, most often linked to human interventions. To understand these interventions in more detail, we could, for instance, analyze the pollen grains preserved in the sediments, produced by plants that lived around our sedimentary basins (study locations), and thus reconstruct changes in cultivation and agriculture. Even though this method, known as palynology, allows for a high degree of precision in identifying specific plant species or families and establishing changes in their presence over time, it likewise remains only an approximation. We are able to reconstruct relative changes, but we are often unsure of the exact spatial signature of vegetation dynamics: while the pollen of certain plants such as vines or cereals is dispersed in a relatively local radius, that of others such as olive and pine trees travels over long distances, often confounding local and regional signals in a single dataset.[10] A variety of other techniques allow for the evaluation of human impact on landscapes, notably the analysis of an array of biomarkers—specific organic compounds reflecting the presence of plants or animals in the past, such as beta-stanols from the excrement of omnivores, usually pigs or humans.[11] None of these markers allows for a direct measurement or reconstruction of past ecosystems or human activities in the landscape, but together they permit reliable approximations that historians and archaeologists can further contextualize with the help of written and material sources.

The stories we tell about the past are located in specific places and relate to specific moments in time. Historians use time and space to structure narratives—we study a specific *problem* in a particular *when and where*. To a large extent, it is also time and space that define specializations and subdisciplines within academic history: most historians are specialists in a particular time period in certain geographical areas. This is far less often the case with natural scientists, whose specialization is frequently method-based. Not surprisingly, historians exploring the potential for integrating natural scientific data and insights into their research usually begin by surveying the data available within a specific spatiotemporal framework. Often, we look for overlaps between these data and a given research topic and start building new histories once these overlaps are found. Reliable approximations of time and space thus become crucial for integrating diverse lines of evidence from often radically different disciplines. Before we consider concrete examples of different study designs, methodological contexts in which humanistic and natural scientific communities interact and in which the datasets they produce become entangled,

10. Adam Izdebski, "Palynology and Historical Research," in *A Companion to the Environmental History of Byzantium*, ed. Adam Izdebski and Johannes Preiser-Kapeller (Leiden: Brill, 2022).

11. For example, Robert M. D'Anjou et al., "Climate Impacts on Human Settlement and Agricultural Activities in Northern Norway Revealed through Sediment Biogeochemistry," *Proceedings of the National Academy of Sciences* 109, no. 50 (2012): 20332–37.

we must first focus on how spatial and temporal scales are conceived and approximated in the natural scientific disciplines that most frequently interact with Late Holocene history.

## The Epistemological Challenges of Using Proxy Data: Climate Phenomena and Climatic Proxies

Climate-related phenomena can be local, regional, hemispheric, or global, and thus define the spatial relevance of proxy records. As a consequence, when we examine the spatial scales of historical climate change we are often faced with a perplexing diversity. To begin with, we have relatively rare global or hemisphere-wide phenomena, often associated with specific types of forcing such as strong tropical volcanic eruptions or El Niño–Southern Oscillation (ENSO). These, in turn, translate differently into regional climates, prompting for instance shifts in seasonal rainfall patterns on a semi-continental scale, related to monsoons or surface temperature changes in the oceans. Finally, due to microclimatic and microregional variation, the same hemispheric or even regional climatic phenomena can have different—even opposite—local effects, depending on a wide range of factors that might include land-sea interactions, vegetation, and land morphology. Trends in temperature variability are more likely to be homogeneous over larger areas (often on a continental or sub-continental scale), whereas hydroclimate (rain, snow, actual soil-level humidity, etc.) can vary significantly on regional and local scales.

In order to appreciate the spatial issues involved in proxy interpretation, let us look more closely at the proxy of (mainly) winter hydroclimatic conditions at Lake Nar in central Anatolia. As mentioned above, modern meteorological data (measured by instruments) are used to understand which climate phenomena are reflected in particular proxies. These modern data can also be used to understand the spatial relevance of the proxy, or which areas it actually “represents.” Figures 1 and 2 show statistically significant spatial correlations of autumn-winter precipitation conditions from Lake Nar and the surrounding area on two timescales: thirty and sixty years. As we can see, on a shorter timescale of roughly one human generation, or thirty years (fig. 1), the Lake Nar proxy record would be relevant mostly for central Anatolia (ca. 0.8 spatial Spearman correlation[12]), less so for the rest of Anatolia (ca. 0.6 correlation), and even less for Bulgaria, Romania, and south-western Ukraine, where only half of

12. Spearman’s correlation coefficient measures the strength and direction of the monotonic relationship between two variables. The Spearman rank correlation test does not carry any assumptions about the distribution of the data (unlike the Pearson correlation, which requires normally distributed variables) and is the appropriate correlation analysis when the variables are measured on a scale that is at least ordinal. Spearman’s correlation coefficients range from -1 to +1. The sign of the coefficient indicates whether it is a positive or negative monotonic relationship. A positive correlation means that as one variable increases, the other variable also tends to increase. A negative correlation signifies that as one variable increases, the other tends to decrease. Values close to -1 or +1 represent stronger relationships than values closer to zero.



https://doi.org/10.1017/ahsse.2022.21 Published online by Cambridge University Press

**Figure 1. Spatial Spearman correlation of autumn-winter precipitation between Lake Nar and surrounding areas, 1981–2010**

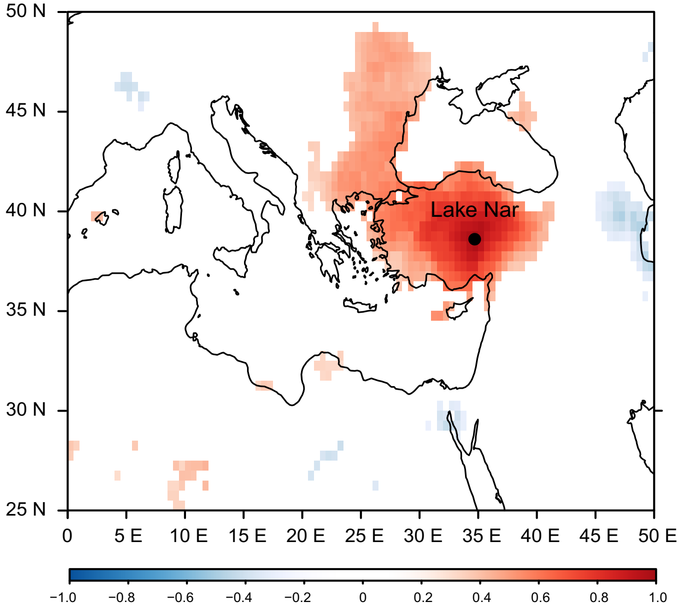
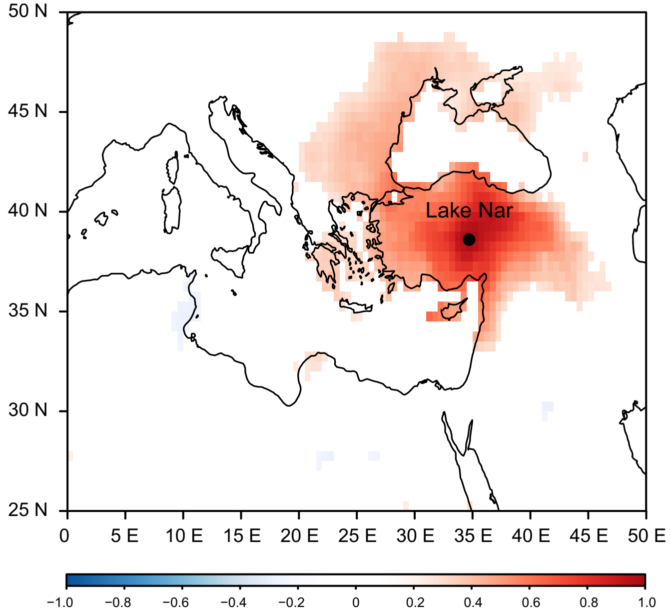



**Figure 2. Spatial Spearman correlation of autumn-winter precipitation between Lake Nar and surrounding areas, 1951–2010**




*Note: in both figures precipitation time series are detrended by removing the long-term linear trend.*



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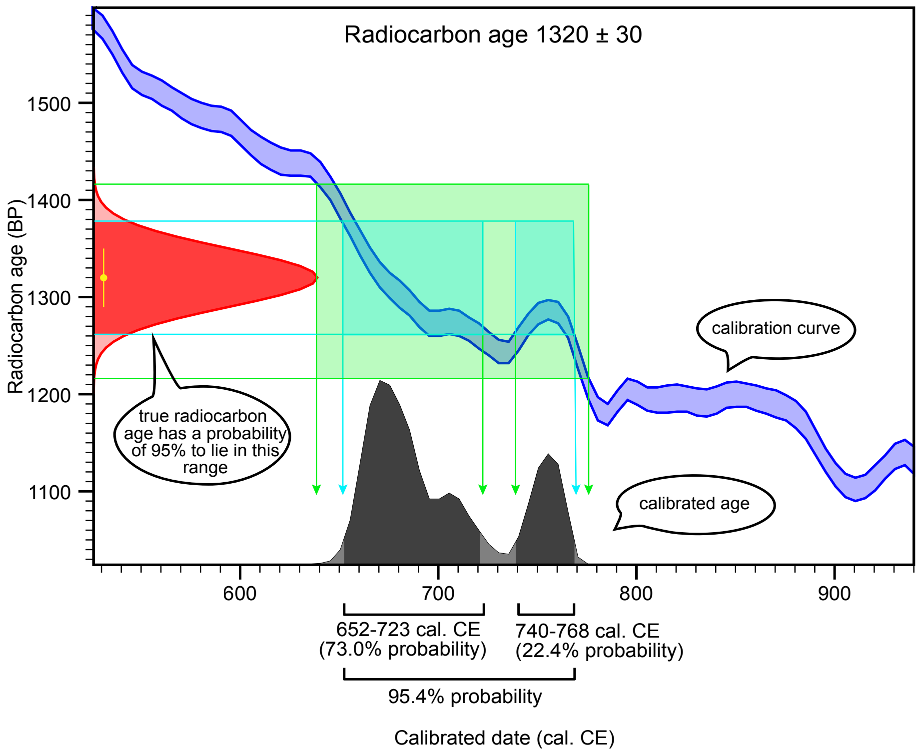
autumn-winter precipitation would follow a similar pattern to the Lake Nar area. If we move to a longer timescale of sixty years (fig. 2), spatial correlation values over areas that are not in the immediate vicinity (that is, outside central Anatolia) decrease, but a larger area is covered by weaker but still statistically significant correlations: this now extends to southern Greece, as well as the northern parts of Iraq and the Levant. This example clearly demonstrates the need to consider spatial as well as temporal scales when using a proxy in historical analysis. Lake Nar can definitely be used to write a climate history of central Anatolia, but the trends it shows should not be used for other parts of the Mediterranean unless they are corroborated by other proxies; we should also remember that only some of the longer-term trends are shared between proxies (and this, too, is inconsistent over time[13]). There is thus no single Mediterranean or even eastern Mediterranean history of climate.[14] The temporal precision of the proxy, in turn, depends not on the specifics of the climate phenomenon the proxy represents, but first and foremost on the natural archive from which it was derived, whether a lake bed, peat bog, cave stalagmite, tree, or something else. In some cases, palaeoclimatologists can develop annually resolved climate reconstructions (for instance, based on tree rings), but usually they deal with multi-decadal or centennial resolution in their datasets. The distance between individual data points in a proxy can thus be a single year, decades, or even centuries—and these chronologies can be characterized by a degree of uncertainty that often ranges from a year or two to several decades.

This has to do with the radiometric dating methods, such as $^{14}C$ (Carbon-14) or Uranium-series dating, that are widely employed for developing proxy chronologies. Scientists measure the radiometric properties of selected samples from different core or speleothem depths, which, due to the sediment accumulation process, represent different "dates," or locations in time. They then extrapolate from those measurements to develop an age-depth model that can be used to provide all other samples with age estimates (which are not dates as such). Radiometric methods, like any measurement, have their associated margins of error. Even if continued technological advances mean that these can be relatively small, not all material is suitable for dating and the recovery of good samples is random: some parts of the core end up being better dated than others. The chronological uncertainty associated with radiometric methods is further compounded by the need to perform a calibration process. In the case of $^{14}C$ dating, this calibration relies on a comparison of radiocarbon measurements with known calendar dates, such as those obtained through dendroclimatological[15] methods (fig. 3).

13. Inga Labuhn et al., "Climatic Changes and their Impacts in the Mediterranean during the First Millennium A.D.," in *Environment and Society in the Long Late Antiquity*, ed. Adam Izdebski and Michael Mulryan (Leiden: Brill, 2018), 65–88.
14. John Haldon et al., "Plagues, Climate Change, and the End of an Empire: A Response to Kyle Harper's *The Fate of Rome* (1): Climate," *History Compass* 16, no. 12 (2018): https://doi.org/10.1111/hic3.12508; Timothy P. Newfield, "The Climate Downturn of 536–50," in *The Palgrave Handbook of Climate History*, ed. Sam White, Christian Pfister, and Franz Mauelshagen (London: Palgrave, 2018), 447–93, especially pp. 467–74.
15. That is, analyses based on the spacing between annual growth rings of trees.

**Figure 3. Example of radiocarbon calibration from Lake Engir in Anatolia (measured "raw" $^{14}$C age of 1320 ± 30)**




*Note: the vertical axis shows the radiocarbon measurement (yellow line) with its theoretical probability distribution (red = one standard deviation, 67% probability; light red = two standard deviations, 95% probability). The blue line is the northern hemisphere radiocarbon calibration curve. The horizontal axis shows the calibrated probability distribution (black = one standard deviation, 67% probability; gray = two standard deviations, 95% probability).*

*Source: prepared with the OxCal v4.3.2, Christopher Bronk Ramsey, "Methods for Summarizing Radiocarbon Datasets,"* Radiocarbon *59, no. 6 (2017): 1809–33; IntCal13 atmospheric calibration curve, Paula J. Reimer et al., "IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP,"* Radiocarbon *55, no. 4 (2013): 1869–87.*

The process of calibrating a radiocarbon measurement will result in a chronological uncertainty that can vary considerably with temporal segments within the calibration data (for instance, uncertainties can be larger for one half-millennium and smaller for another). All this means that, in the majority of cases, when using palaeoenvironmental data one operates at the level of decades, half-centuries, or even centuries, rather than the annual or monthly scales of *histoire événementielle*.

Another example can help explain these complex problems. Let us look again at central Anatolia, this time at Lake Engir, not far from Lake Nar. Sediments from both lakes have been subjected to pollen analysis, and both show that mixed-farming agriculture (combining crops and livestock) collapsed in Cappadocia



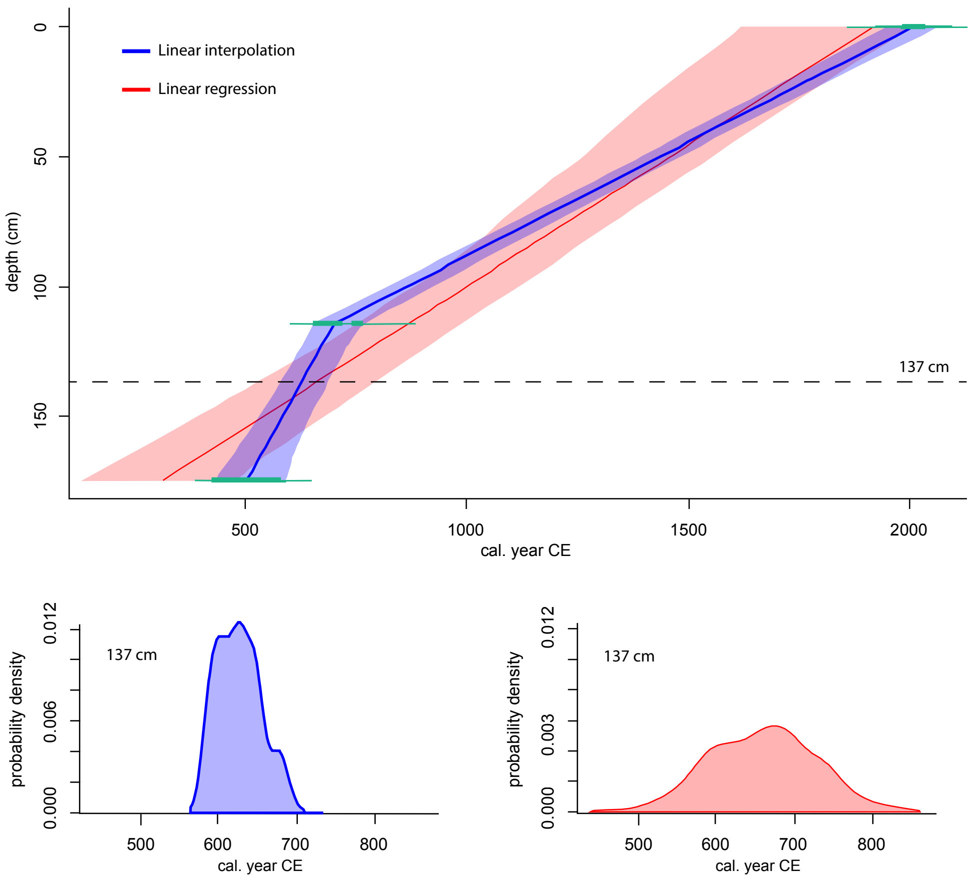
https://doi.org/10.1017/ahsse.2022.21 Published online by Cambridge University Press

at the end of antiquity. The problem is the precise date of this change. While Lake Nar's varved sediments mean that it can be pinpointed to the 660s CE,[16] the chronology of Lake Engir is based on two radiocarbon dates: 1320 ± 30 years Before Present (BP) at 114.5 cm and 1540 ± 30 years BP at 175 cm.[17] The change in the sediments occurs at the depth horizon of 137 centimeters; it is therefore crucial to correctly estimate the age of the sample taken from the 137th centimeter of the core. With two radiocarbon dates, this can be done using two age-depth models: linear regression and linear interpolation. Technically, linear interpolation is a stepwise linear regression that involves interpolating estimated ages between $^{14}C$ dates and the surface (i.e., the date in the early twenty-first century at which the core was taken), with different linear functions for each of the two sections of the core—that is, between the two dates and between the second date and the surface (fig. 4). Estimating sample age based on an age-depth model is a matter of probability: we do not obtain precise data but rather a distribution of probability over time, which shows where the actual (unknown) date most probably falls. Thus, we see that for the sample from the 137th centimeter the linear regression model (red) "spreads" this probability over three hundred years, while the linear interpolation (blue) restricts the distribution more or less to the seventh century, pointing to its earlier part. The choice of model, in the end, depends on mathematical and geological arguments (and more complex models are usually better), though here both models show it is highly probable that the agricultural collapse at Engir was roughly synchronous with the similar change at Nar. It should be emphasized that the Lake Engir model is a simple one—such models can contain dozens of radiocarbon dates and might involve major breaks or irregularities in the sedimentation process, significantly complicating the age-estimation process.

If we return to the historiography, we can place this problem in the context of how recent generations of historians have thought about time. It is evident that the change the historical discipline is currently undergoing, together with recent advances in the palaeosciences, can also be understood as a redefinition of the Braudelian structure of historical time. The (sub)centennial and regional scale of much of the palaeoenvironmental data is exactly the medium-term level of change at which Fernand Braudel located the social and the economic.[18] With the increasing availability of palaeoenvironmental data, it has also become possible to translate environmental phenomena from Braudel's deep level of the *longue durée*, where no humanly perceptible change occurs, to the level of the medium-term, where "common destinies" and "trends"—including climatic trends,

16. Ann England et al., "Historical Landscape Change in Cappadocia (Central Turkey): A Palaeoecological Investigation of Annually-Laminated Sediments from Nar Lake," *The Holocene* 18, no. 8 (2008): 1229–45.
17. Çetin Şenkul et al., "Late Holocene Environmental Changes in the Vicinity of Kültepe (Kayseri), Central Anatolia, Turkey," *Quaternary International* 486 (2018): 107–15.
18. Fernand Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II* [1949], 2 vols., trans Siân Reynolds (1972–1973; Berkeley: University of California Press, 1995); Braudel, "Histoire et Sciences sociales. La longue durée," *Annales ESC* 13, no. 4 (1958): 725–53.

**Figure 4. Age-depth model of Lake Engir sediment core and the estimated age probability distribution for the depth of 137 cm**




*Note: the model represented in blue shows linear interpolation between data points; that in red shows linear regression and the estimated age probability distribution for the depth of 137 cm (the sample showing the transition between late antique agriculture and early medieval land abandonment). In the top panel, the green lines represent the two radiocarbon measurements with their probability distribution, plus the surface of the core (early twenty-first century). The blue and red lines show the best single age estimate for each core depth in each age-depth model; the light blue and red areas show the 95% probability distribution of the age estimate in each age-depth model. The lower panels show what the probability distributions for a specific section of the core depth (137 cm) actually look like in detail, depending on the model (blue = linear interpolation; red = linear regression).*

*Source: graphics executed in the age-modeling code CLAM: Maarten Blaauw, "Methods and Code for 'Classical' Age-Modeling of Radiocarbon Sequences,"* Quaternary Geochronology *5 (2010): 512–18. The radiocarbon dates come from Çetin Şenkul et al., "Late Holocene Environmental Changes in the Vicinity of Kültepe (Kayseri), Central Anatolia, Turkey,"* Quaternary International *486 (2018): 107–15.*

or *conjonctures climatiques*, as Emmanuel Le Roy Ladurie would call them[19]—occur, with changes taking place at a relatively fast pace from one generation to the next or even quicker. This does not mean that there are no long-term processes in the Braudelian sense, nor that "environmental" histories occur only at medium-term timescales. Rather, the processes are defined by their pace and not by their specificity: the environmental accompanies the social and the economic, as well as the political and the cultural, at every timescale on which the phenomena we study actually occur.

Along these lines, some participants in more recent debates on the *longue durée* have suggested that to work properly with longer-term perspectives in historical studies it is necessary to deconstruct or break down the long-term into finer temporal scales. This should, they argue, make it possible to understand the social processes that form the basis of centennial trends.[20] Unsurprisingly, the French historians of the Annales school proposed similar strategies three decades ago as they attempted to resolve the deadlocks of quantitative history: their most common solution was to understand the specific events of microhistory as models for larger-scale phenomena,[21] so that a successful study of quantitative trends would necessarily combine the longer-term approach with a more microhistorical, or at least higher-resolution and qualitative, historical method.[22] With the current explosion of palaeoenvironmental data, historians are not limited to combining quantitative and narrative approaches from within the historical discipline itself, but can also integrate evidence from outside the humanities and social sciences into their

19. A term he used for the first time in a paper published more than fifty years ago: Emmanuel Le Roy Ladurie, "Aspects historiques de la nouvelle climatologie," *Revue historique* 225, no. 1 (1961): 1–20.

20. Christian Lamouroux, "Chronological Depths and the *Longue Durée*," *Annales HSS (English Edition)* 70, no. 2 (2015): 285–91.

21. The "question of scale" was one of the major concerns during the "crisis" of the *Annales* in the 1980s; see "Histoire et sciences sociales. Un tournant critique ?" *Annales HSS* 43, no. 2 (1988): 291–93. For a fuller treatment of the debate over micro vs. macro scales of analysis in French historiography, see Jacques Revel, "Micro-analyse et construction du social," in *Jeux d'échelles. La micro-analyse à l'expérience*, ed. Jacques Revel (Paris: Gallimard/Éd. du Seuil, 1996), 15–36; Revel, "Paysage par gros temps," in *La forza delle incertezze. Dialoghi storiografici con Jacques Revel*, ed. Antonella Romano and Silvia Sebastiani (Bologna: Il Mulino, 2016), 353–69.

22. Such approaches have also been pioneered within the broader tradition of the Annales school, if we consider the work of the Genoa-based Laboratory of Environmental History and Archaeology led by Diego Moreno. In this case, detailed historical work, particularly in the field of historical geography, provides a new basis for the interpretation of archaeological finds and palaeoenvironmental data. See, for instance, Giulia Beltrametti et al., "Les cultures temporaires, entre longue durée et chronologie fine (Montagne ligure, Italie)," in *Cultures temporaires et féodalité. Les rotations culturales et l'appropriation du sol dans l'Europe médiévale et moderne*, ed. Christine Rendu and Roland Viader (Toulouse: Presses universitaires du Midi, 2014), 235–58; Valentina Pescini, Carlo Alessandro Montanari, and Diego Teodorico Moreno, "Multi-Proxy Record of Environmental Changes and Past Land Use Practices in a Mediterranean Landscape: The Punta Mesco Cape (Liguria – Italy) between the 15th and 20th Century," *Quaternary International* 463 (2018): 376–90.

work. Combining different types of environmental proxies with archaeological and textual evidence makes it possible to narrow the range of hermeneutic possibilities and limit the extent of potential interpretations, not least when it comes to the temporal and spatial scale of the phenomena we study.

Historians working at the crossroads of history and archaeology or geology were among the first to confront this challenge. Twenty years ago, for instance, the landscape historian Gérard Chouquer argued that instead of seeing different disciplines as supplying information on different "layers" of temporality—from the deep(er) past of geologists to the contemporary human-natural space of geographers—scholars should work together, with the resources at their disposal, to address phenomena of interest along spatiotemporal scales relevant for a particular study.[23] Indeed, the progress that palaeoscientific approaches have achieved in the last decade, both in the range of phenomena they can reconstruct and in the temporal accuracy of their methods, means that many problems faced by earlier generations of historians who pioneered collaboration with the earth sciences are gradually disappearing. As the earth sciences increase their focus on the origins of the Anthropocene, there is justified hope that even better synergy will emerge between scholars from the humanities and those from the earth sciences.

What follows will present examples of interdisciplinarity in practice. We have decided to focus on three groups of studies that represent what we consider to be the most common models currently linking historical research with natural scientific data in the field of environmental history: broad-stroke survey-type studies, more focused quantitative studies, and interdisciplinary studies supporting new readings of textual sources.

## Survey-Type Studies: Bringing Together Disparate Datasets

Survey-type studies were the earliest examples of interdisciplinary environmental history. They can be described as attempts to lend historical context to natural scientific data, sometimes created much earlier or over a long period, often independently from traditional historical questions such as the fall of the Roman Empire or the Thirty Years' War. In other words, historians work with the scientists who produced the data and seek to provide them a posteriori with historical meaning and significance. Over the last two decades, most such studies have focused on past climate.[24]

23. Gérard Chouquer, *L'étude des paysages. Essais sur leurs formes et leur histoire* (Paris: Errance, 2000), 170–75.

24. The most comprehensive were probably two studies focused on the late antique world: Michael McCormick et al., "Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence," *Journal of Interdisciplinary History* 43, no. 2 (2012): 169–220; and John Haldon et al., "The Climate and Environment of Byzantine Anatolia: Integrating Science, History and Archaeology," *Journal of Interdisciplinary History* 45, no. 2 (2014): 113–61. Another well-known example is Büntgen et al., "Cooling and Societal Change during the Late Antique Little Ice Age." The survey-type approach can also be deployed on a larger scale, even within a historical

This early model of survey-type studies often included a delicate yet important marketing aspect, with the historical dimension being used mostly to broaden the application of an otherwise typical natural science project and attract publicity. These studies should therefore be understood not simply as historians using scientific "products," but also as the sciences (or rather, natural scientists) using history to validate their claims and infuse their findings with additional significance.[25] It is vital to mention this question of instrumentalization early on in our discussion, because considerable tension and even power struggles can be threaded through interdisciplinary projects and the use and interpretation of scientific data. When engaging with the palaeosciences, historians can often be drawn into debates with which they are only partially familiar, if at all. This may lead to the overemphasizing of a specific dataset's historical significance or the disregarding of source criticism and the limits of plausible historical interpretation. History can be misused and the work of historians misinterpreted.[26] At the same time, the opposite can also occur: scientists can unknowingly intervene and even take a side in a subject of considerable historiographical debate, giving one interpretation the advantage of being supported by the "objective" natural scientific data.

A recent example of this approach reveals both its weaknesses and its strengths.[27] Importantly, the fact that many of the present article's authors were also involved in this 2016 publication means that we can analyze it from a critical

monograph, as demonstrated by Adam Izdebski, *A Rural Economy in Transition: Asia Minor from Late Antiquity into the Early Middle Ages* (Warsaw: Taubenschlag Foundation, 2013). A recent example of a large-scale application of this approach is Lee Mordechai et al., "The Justinianic Plague: An Inconsequential Pandemic?" *Proceedings of the National Academy of Sciences* 116, no. 51 (2019): 25546–54.

25. See Kristina Sessa, "The New Environmental Fall of Rome: A Methodological Consideration," *Journal of Late Antiquity* 12, no. 1 (2019): 211–55.

26. There are numerous examples of such situations. For instance, a study presenting a record of lead pollution in a Greenland ice core—most probably related to silver production in Iberia and France during antiquity and the early Middle Ages—was broadly promoted as a reconstruction of Roman GDP, even though the study itself did not go beyond inferences about Roman economic growth (McConnell et al., "Lead Pollution Recorded in Greenland Ice"). Perhaps even more revealing is the career of the "Digitizing Historical Plague" dataset made available in 2012 by a team consisting predominantly of climate scientists: the dataset is based on a positivistic reading of an incomplete and western Europe-focused catalog of late medieval and early modern plague outbreaks published in the 1970s, not meant to be used as a complete quantitative dataset on European plague in preindustrial times. See Ulf Büntgen et al., "Digitizing Historical Plague," *Clinical Infectious Diseases* 55, no. 11 (2012): 1586–88, based on Jean-Noël Biraben, *Les hommes et la peste en France et dans les pays européens et méditerranéens*, 2 vols. (Paris/The Hague: Éd. EHESS/Mouton, 1975). Since its publication, and especially since March 2020, this dataset has served as the basis for many papers on the epidemiology, demography, economic impacts, etc., of the Black Death and later outbreaks of plague in Europe.

27. Laura Sadori et al., "Climate, Environment and Society in Southern Italy during the Last 2000 Years: A Review of the Environmental, Historical and Archaeological Evidence," *Quaternary Science Reviews* 136 (2016): 173–88.

angle. Sicily, where the study was focused, is a particularly fertile terrain for exploring the relationships between climate and society in the preindustrial era, on the one hand, and the historical and environmental data, on the other. The island has an abundance of human records, both written and material, and is situated in a region with a heightened vulnerability to contemporary climatic change. There is thus a wealth of data—produced over a number of years by different natural scientific, historical, and archaeological projects—that can be pulled together to create a new narrative of its environmental history over the *longue durée*.

Throughout the first millennium CE, Sicily was a unique place. Part of the Roman Empire from the late third century BCE, at the end of Mediterranean antiquity it became a province of the Western Roman Empire. When that collapsed in the fifth century, after an Ostrogothic interlude the island was integrated into the Eastern Roman Empire. Sicily thus remained under imperial Roman control until the Arab conquest of the ninth century. During that time, it experienced significant long-term changes in climate, seemingly extensive enough to have altered the agricultural productivity of the island. The study discussed here was carried out by a team of natural and social scientists, focusing on the interplay of climatic shifts and social-ecological processes in late antique Sicily.[28] By considering the methodological aspects of their work, we hope to show in more detail how historians and natural scientists combine different types of data to develop potential scenarios of social-ecological change and how they typically evaluate their plausibility in a survey-type study.

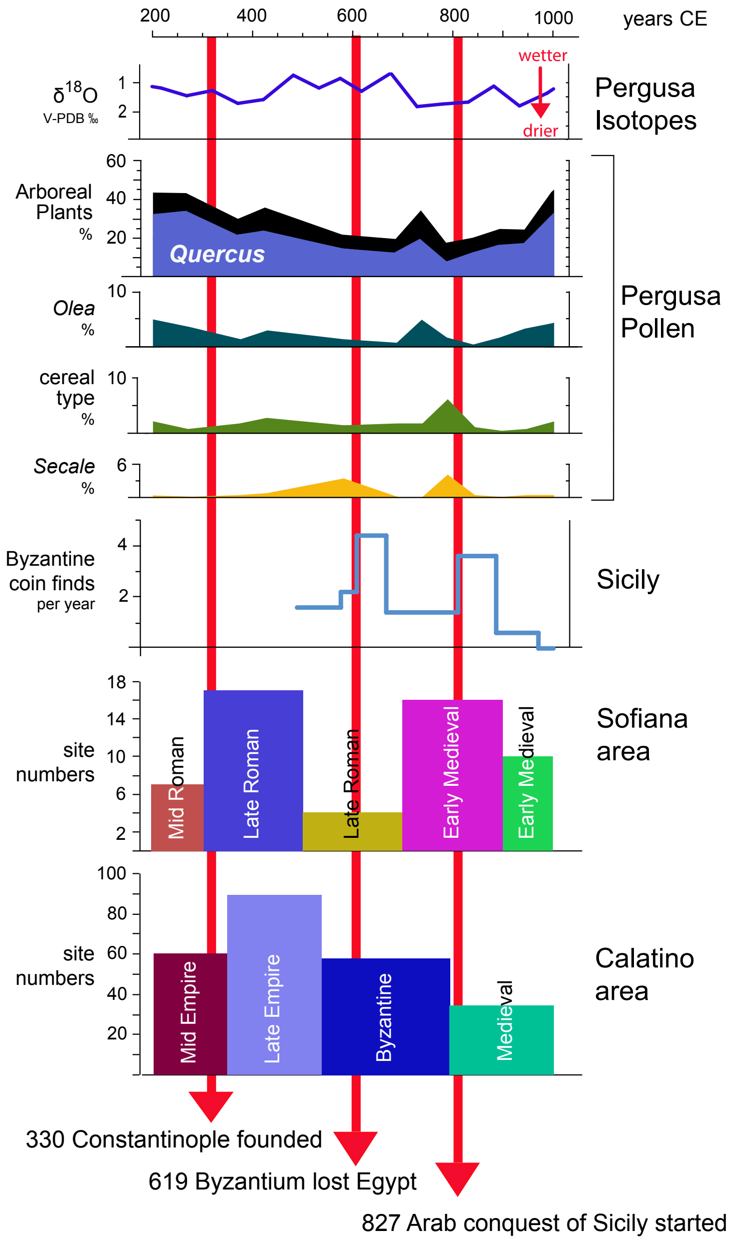
The point of departure for this interdisciplinary research was a multi-proxy study of a sediment core from Lake Pergusa, located in the central east of the island.[29] A single sediment core, or "mud column," was retrieved from the bottom of the lake and sampled according to several analytical techniques. Applying different scientific approaches to the same core ensured that there would be no uncertainty regarding the chronological relationship between the results produced. The sediments were analyzed in particular for pollen—used to reconstruct past vegetation cover and agricultural history—and oxygen isotopes ($\delta^{18}O$)—used to reconstruct winter rainfall, as in the context of Lake Pergusa the proportion of different oxygen isotopes is linked to precipitation and evaporation. The core was radiocarbon dated and provided with a relatively robust age-depth model, which resulted in chronological uncertainty (a confidence interval) of around fifty years for both pollen and isotopes. Existing pollen and palaeoclimatic data from other Sicilian and southern Italian sites were also taken into account, thus expanding the spatial coverage of the analysis. In terms of the quantitative evidence for socioeconomic processes, the study drew on numismatic data (the presence of Eastern Roman coinage on Sicily) as well as archaeological survey datasets (rural settlement counts); it also referred to other archaeological material, mainly pottery, in its final interpretations (fig. 5).

28. Ibid.
29. A multi-proxy study employs a number of different analytical techniques to study material from the same sediment core, which allows the reconstruction of a greater number of different environmental variables.



https://doi.org/10.1017/ahsse.2022.21 Published online by Cambridge University Press

**Figure 5. Palaeoenvironmental data from Lake Pergusa, together with numismatic and rural settlement data from Sicily**




*Source: based on Laura Sadori et al., "Climate, Environment and Society in Southern Italy during the Last 2000 Years: A Review of the Environmental, Historical and Archaeological Evidence,"* Quaternary Science Reviews *136 (2016): 173–88; figure modified after Adam Izdebski et al., "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 (2016): 5–22.*



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The study argued for a strong four-sided correlation over a period of three hundred years (from the mid-fourth to the mid-seventh century) between (1) an increase in winter precipitation, as evidenced in oxygen isotope measurements; (2) a dearth of evidence for any arboreal expansion which would, in the region, typically occur in periods of rising humidity (without, that is, the human interference that was a feature of this period); (3) an expansion of cereal and olive cultivation, visible in the pollen data; and (4) a discernible increase in rural site density from the mid-fourth to at least the mid-seventh century. The authors suggested that the rise in winter rainfall (1) should have facilitated both an increase in farming and visible human impact on the landscape (2 and 3), as well as rural settlement expansion (4), particularly on the marginal, less-fertile lands of the usually dry island. It is important to note, however, that while there is no doubt about the temporal relationships between phenomena (1), (2), and (3), as they are reconstructed from the same sediment core, the correlation with phenomenon (4) remains problematic. The dating of rural settlements depends on ceramic typo-chronologies, the resolution of which can range from decades to centuries. Moreover, these typo-chronologies are subject to change as research on ancient ceramics progresses.[30] The association between phenomena (1) and (2) and phenomenon (4) thus remains a picture painted in broad strokes, based on approximate chronological association and the assumed causal link between an increase in rural site numbers and an expansion of agricultural activities.

The interdisciplinary study on Sicily placed this potentially climate-related rural economic expansion in the context of a relatively well-known phenomenon: the contemporary growth of grain markets in the eastern Mediterranean, Italy, and North Africa following the foundation of Constantinople in 330 CE.[31] Importantly, the authors refrained from arguing for a strong causal link between climate, environment, and societal developments despite the relatively high temporal correlation between the climatic, environmental, and human phenomena observed, recognizing that human factors such as the foundation of Constantinople and its consequences were in themselves sufficient to explain the visible socio-ecological changes, or phenomena (2), (3), and (4). While climate may have played a part in these developments, its role was not necessarily causal. Rather, it may have offered a context in which certain socioeconomic processes could take place more efficiently. In this sense, it could be seen as an amplifier, facilitating the social-ecological change identified in the analysis.

30. Philip Bes, *Once Upon a Time in the East: The Chronological and Geographical Distribution of Terra Sigillata and Red Slip Ware in the Roman East* (Oxford: Archaeopress, 2015); David K. Pettegrew, "Regional Survey and the Boom-and-Bust Countryside: Re-Reading the Archaeological Evidence for Episodic Abandonment in the Late Roman Corinthia," *International Journal of Historical Archaeology* 14, no. 2 (2010): 215–29; Andrew Bevan et al., "Measuring Chronological Uncertainty in Intensive Survey Finds: A Case Study from Antikythera, Greece," *Archaeometry* 55, no. 2 (2013): 312–28.
31. Domenico Vera, "Fra Egitto ed Africa, fra Roma e Costantinopoli, fra annona e commercio. La Sicilia nel Mediterraneo tardoantico," *Kokalos* 43/44 (1997): 33–72.



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The authors observed another interesting fact, namely a sequence of (a) declining winter precipitation starting in the late seventh century; (b) contracting cereal cultivation, which led to land abandonment and woodland expansion and was preceded by a short-term rise in rye, a drought-adapted cereal species; (c) a demonetization of the island; and (d) the waning of Sicily's political significance within the Eastern Roman Empire and its final conquest by the Arab rulers of North Africa. As in the previous example, the temporal relationship between phenomena (a) and (b) is certain, as the data come from the same sediment core. The numismatic data are likewise characterized by a high degree of chronological precision.[32] Moreover, as the article notes, the decrease in coin deposition in Sicily was possibly related to broader economic and political processes, not least the general demonetization of the Byzantine economy and the imperial government's fading interest in the island.[33]

What remains elusive, however, is the temporal connection between phenomena (a), (b), and (c) and phenomenon (d), the Arab conquest of the island. A chronological sequence of events is not enough to prove a causal connection between them (nor is temporal correlation), and the authors of the study were unable to provide further evidence to support the hypothesis that climatic deterioration weakened the island's Byzantine social-economic system and led to its failure in the face of the Arab conquest. Notably, they remark that the Arab conquest of Sicily was very gradual—taking place over nearly a century—and that Byzantine political-military circumstances and the local (Italian) political situation suffice to explain both the Arab victory and the snail's pace of the conquest. There was thus no collapse as such, but rather a slow process of conquest and socioeconomic transformation, which may have been in part triggered by a change in the regional winter precipitation regime that set in during the late seventh and early eighth centuries.

This study showcases both the potential and the shortcomings of the purely quantitative approach usually favored by palaeoenvironmental scientists, who often encourage historians and archaeologists to provide "numbers" that enable inherently quantitative palaeoclimatic and palaeoenvironmental reconstructions to be fitted with what are often inherently qualitative written sources. Studies like the Sicilian one can reveal intriguing co-occurrences and sequences, or indeed a lack of temporal connection, between climatic, environmental, and societal phenomena, but they are limited when it comes to establishing plausible causal links. Such

32. This is true as long as we consider only the chronology of their issuing: coins could remain in use for much longer periods and it is difficult to provide a general estimate for how long they might circulate. For further discussion, see Marcus Phillips, "Currency in Seventh-Century Syria as a Historical Source," *Byzantine and Modern Greek Studies* 28, no. 1 (2004): 13–31.

33. As the authors observe, this may have been linked to Sicily's decreasing agricultural productivity, so central to the interests of the imperial government in its struggle for survival against the caliphate: Sadori et al., "Climate, Environment and Society in Southern Italy," 182. See also John Haldon, "Some Thoughts on Climate Change, Local Environment, and Grain Production in Byzantine Northern Anatolia," in Izdebski and Mulryan, *Environment and Society in the Long Late Antiquity*, 200–206.



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approaches can serve as a useful first step in exploring the connections between climate and society, but the fragmentary and heterogeneous nature of the various types of data means that they cannot provide us with the type of answers that historians or environmental scientists often seek. In other words, the extent to which datasets created in different projects, with different agendas, can be used for other purposes, remains an open question. Nevertheless, these datasets are regularly incorporated into new projects, often with little consideration of their pros and cons. As long as this happens within the context of a similar line of inquiry or within the same field, it is usually not that problematic. However, when data originating in one field are used to answer questions in another, and as part of that transfer are detached from their original research context, important interpretational issues, with the potential to compromise final conclusions, may emerge.

To improve this common approach of combining palaeoclimatic reconstructions with the fruits of historical research, we need to ensure that all types of evidence mobilized—historical, archaeological, environmental, and so on—are operating at the same spatial, societal, and temporal scales. This is not always easy, as different datasets are frequently the result of disparate analyses: the final products were never truly designed to overlap with each other. The same is true in the palaeosciences. Most scientists collect only part of the data they use to arrive at their final conclusions themselves, instead incorporating substantial amounts of existing information. Bringing more data to the table has obvious advantages, facilitating larger-scale analyses and even interdisciplinarity, but it also means that authors risk losing control over the data employed and weakening the precision of their study. One solution to this problem is to invite the relevant specialists to join the study, which of course can heighten the complexity of the research but may also raise logistical problems and slow the project down. Nor does an interdisciplinary approach offer a magic bullet: researchers tend to be constrained by the nature of their evidence, so that comparison and correlation testing of differently calibrated time series potentially amounts to comparing incomparable variables. For this approach to be really effective, such studies should ideally result from workshops focused on specific research questions embedded in a clear spatiotemporal framework. Even better would be to establish more permanent interdisciplinary teams geared toward the restructuring of already existing series and, whenever necessary, producing new, ready-calibrated data.

## The Pitfalls and Potential of Quantification and Statistical Inference

Sources that contain deliberate, continuous, and systematic hydrometeorological, atmospheric, or astronomical observations (for instance, recording potentially weather-relevant sunspot, auroral, or dust-veil phenomena) are highly prized, particularly for pre- or early instrumental periods—for Europe, this means roughly before the eighteenth century, when meteorological measurements began to be systematically taken and recorded across the continent. Such sources include weather



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diaries, sometimes made by trained professionals but often the virtuoso productions of keen amateur observers. These texts employ set terminologies to describe climate phenomena and their intensity or duration, reflecting their authors' attempts to limit the subjectivity of their descriptions. In Europe, they are principally available from the later medieval period on,[34] but systematic environmental observations were certainly maintained elsewhere in other—often institutional—contexts, with standout examples being the Babylonian astronomical diaries that survive from the seventh to first centuries BCE and Egyptian Nilometer records.[35]

Being readily quantifiable, such sources have advanced our understanding of past climatic changes and their societal consequences.[36] But so too have more qualitative sources, with, for example, medieval annals and chronicles furnishing records of extreme weather, political events, and social behaviors that researchers have quantified in frequency and intensity.[37] Annalistic sources have often been sidelined by scientific studies, in part because their focus on singular extreme events prevents a full annual reconstruction of average conditions. Le Roy Ladurie nevertheless argued that even given their limitations, rejecting annalistic sources out of hand would be "hypercritical … flying in the face of texts and wantonly

34. Christian Pfister et al., "Daily Weather Observations in Sixteenth-Century Europe," *Climatic Change* 43 (1999): 111–50; Urs Gimmi et al., "A Method to Reconstruct Long Precipitation Series Using Systematic Descriptive Observations in Weather Diaries: The Example of the Precipitation Series for Bern, Switzerland (1760–2003)," *Theoretical and Applied Climatology* 87 (2007): 185–99; Stephen O'Connor et al., "A Weather Diary from Donegal, Ireland 1846–1875," *Weather* 76, no. 12 (2021): 385–91.

35. Joost Huijs, Reinhard Pirngruber, and Bas van Leeuwen, "Climate, War and Economic Development: The Case of Second-Century BC Babylon," in *A History of Market Performance: From Ancient Babylonia to the Modern World*, ed. Robertus J. van der Spek, Bas van Leeuwen, and Jan Luiten van Zanden (London: Routledge, 2015), 128–48; Johannes Haubold, John Steele, and Kathryn Stevens, eds., *Keeping Watch in Babylon: The Astronomical Diaries in Context* (Leiden: Brill, 2019).

36. These sources can nevertheless exhibit biases. For instance, they often fail to capture longer-term changes in background average climate conditions, especially if such trends occur over or beyond the lifespan of individual observers, as noted by Raymond S. Bradley and Philip D. Jones, introduction to *Climate since A.D. 1500*, ed. Raymond S. Bradley and Philip D. Jones (London: Routledge, 1995), 1–16; and M. J. Ingram, D. J. Underhill, and G. Farmer, "The Use of Documentary Sources for the Study of Past Climates," in *Climate and History: Studies in Past Climates and Their Impact on Man*, ed. T. M. L. Wigley, M. J. Ingram, and G. Farmer (Cambridge: Cambridge University Press, 1981), 180–213. Indeed, a similar challenge is faced when reconstructing long-term changes over centuries and millennia from tree-ring samples that individually span smaller segments of time: Edward R. Cook et al., "The 'Segment Length Curse' in Long Tree-Ring Chronology Development for Palaeoclimatic Studies," *The Holocene* 5, no. 2 (1995): 229–37.

37. See, for example, McCormick et al., "Climate Change during and after the Roman Empire"; Sébastian Guillet et al., "Climatic and Societal Impacts of a 'Forgotten' Cluster of Volcanic Eruptions in 1108–1110 CE," *Scientific Reports* 10 (2020): https://doi.org/10.1038/s41598-020-63339-3; Günter Blöschl et al., "Current European Flood-Rich Period Exceptional Compared with Past 500 Years," *Nature* 583, no. 7817 (2020): 560–66.

refusing to admit witnesses who have a right to be heard."[38] Indeed, more recently event-focused texts have been increasingly used in tandem with natural archives to test specific hypotheses concerning past climatic behavior and societal vulnerability and response, particularly in medieval periods for which other sources are comparatively scarce.[39]

Take, for instance, the surviving corpus of medieval Irish annals, which provide reliable reporting of major historical events starting in the sixth century CE or earlier and ceasing only in the seventeenth century with the disruption caused by English colonial rule.[40] These texts credibly identify some sixty-five severe "cold events" across this period (fig. 6). The information they provide can be combined with evidence for the timing and magnitude of historic explosive volcanic eruptions, which caused elevated fallout of atmospheric sulfate on the Greenland ice sheet and are thus identifiable by sulfate measurements in ice cores extracted from the region. Considering the two together reveals the major influence of explosive volcanism on the climate of the northeast Atlantic region represented by Ireland across more than a millennium.[41] Evidence of severe cold relative to Ireland's mild maritime climatic norm was identified in the written sources (including frost, snow, or general descriptions of cold) and quantified by type, frequency, and seasonality. To allow a count of meaningful correspondences in the dates of cold events and eruptions—that is, those occurring close enough in time to suggest a plausible causal association—it was also necessary to consider the accuracy and precision of the respective ice-core and annalistic chronologies, as well as the timescales of relevant atmospheric and climatic processes, in particular those governing sulfate transport times to Greenland and lag times between eruptions and their climatic impacts. Some thirty-seven cold events (53.6% of those identified) were thus seen to occur within a few years after eruption dates, implying a sizable role for volcanism in the episodes of extreme cold that heavily impacted Irish society.[42]

38. Emmanuel Le Roy Ladurie, *Times of Feast, Times of Famine: A History of Climate since the Year 1000* [1967], trans. Barbara Bray (London: George Allen and Unwin Ltd., 1971), 275.
39. A scarcity that has long been noted: Hubert H. Lamb, *Climate, History and the Modern World* (London: Routledge, 1995). For prominent examples of such usage, see Michael McCormick, Paul E. Dutton, and Paul A. Mayewski, "Volcanoes and the Climate Forcing of Carolingian Europe, A.D. 750–950," *Speculum* 82, no. 4 (2007): 865–95 (as well as the statistical appendix by Nick Patterson); and Christian Pfister et al., "Winter Air Temperature Variations in Western Europe during the Early and High Middle Ages (AD 750–1300)," *The Holocene* 8, no. 5 (1998): 535–52.
40. Daniel McCarthy, *The Irish Annals: Their Genesis, Evolution and History* (Dublin: Four Courts Press, 2008).
41. Francis Ludlow et al., "Medieval Irish Chronicles Reveal Persistent Volcanic Forcing of Severe Winter Cold Events, 431–1649 CE," *Environmental Research Letters* 8, no. 2 (2013): http://dx.doi.org/10.1088/1748-9326/8/2/024035.
42. See Bruce M. S. Campbell and Francis Ludlow, "Climate, Disease and Society in Late-Medieval Ireland," *Proceedings of the Royal Irish Academy* 120C (2020): 159–249; Donnchadh Ó Corráin, "Ireland c. 800: Aspects of Society," in *A New History of Ireland*, vol. 1, *Prehistoric and Early Ireland*, ed. Dáibhí Ó Cróinín (Oxford: Oxford University Press, 2005), 549–608.



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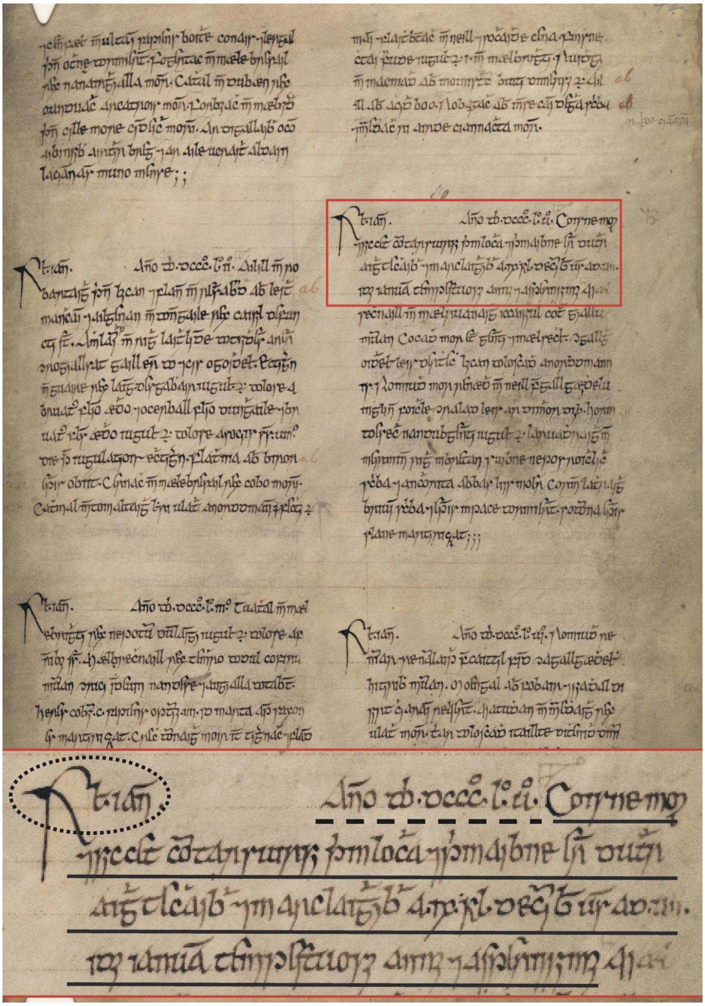
**Figure 6. Page from the Annals of Ulster, showing entries from 852–858 CE**



*Note: in the inset, the encircled text reads "K1. Ianair." This is an abbreviation of the "kalends of January," that is, the first day of January, and marks each annual list of entries. The dashed underlined text gives the* Anno Domini *date in Roman numerals, and the solid underlined text shows the first historical entry for the year 856 (incorrectly given as 855 in the manuscript). This entry reports that "There was much ice and frost so that the principal lakes and rivers of Ireland could be crossed on foot and horseback from the ninth of the kalends of December [November 23, 855] to the seventh of the ides of January [January 7, 856]. A tempestuous and harsh year."*
*Source: Trinity College Dublin MS 1282, the Annals of Ulster, fol. 42r. Reproduced by permission of the Board of Trinity College Dublin.*

The Irish climate can, of course, experience severe cold even without volcanic forcing. But the correlation is a strong one: the probability of such a high level of co-occurrence arising purely by chance is vanishingly small at just 0.03%, reinforcing arguments in favor of the apparent connection.



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Most cold events recorded in the annals were, moreover, reported in winter, regardless of whether they were associated with volcanism. The written evidence thus complements our wider understanding of historic volcanic impacts based on natural (biological) archives such as tree rings, which can usually only provide indications about spring-summer climate during the period of active growth. Some scholars have expressed concern that natural archives are accorded automatic primacy over human archives in studies of our interactions with the environment,[43] but the Irish example shows that the two should be considered complementary. This understanding nonetheless requires an unbiased approach to these archives and the possibilities they present, an effort to learn their respective strengths and limitations, and confidence in what each discipline has to offer. Credible quantification of the Irish evidence required, for example, an understanding of the genealogy of the annalistic texts, which due to their shared ancestry often duplicate reports, and because of scribal errors over time can locate these under different years. This can effectively disguise their duplicate status and mean they are counted twice or more. Understanding the motivations for recording weather was also crucial to identifying reports of dubious veracity: we must consider how extreme events were perceived by both the scribes and their intended audience, including as portents or vehicles of divine retribution, and whether exaggeration or fabrication could serve a political, rhetorical, or theoretical agenda.[44] While earlier efforts in historical climatology were criticized for paying insufficient attention to such concerns,[45] historical expertise is now deemed fundamental to the use of written evidence in climatic reconstruction.[46] Its importance is clear in the Irish example. If, in a hypothetical worst case scenario, all dubious reports were included as genuine and all duplicated reports went undetected, the total number of cold events would increase to 181, an inflation of 178.5%.[47]

Studies such as the Irish example place historians, their sources, and their methods in service to natural scientific questions. Another example, centered on

43. John Moreland, "AD 536 – Back to Nature?" *Acta Archaeologica* 89, no. 1 (2018): 91–111.
44. Francis Ludlow, "Utility of the Irish Annals as a Source for the Reconstruction of Climate" (PhD diss., Trinity College Dublin, 2011); Daniel McCarthy and Aidan Breen, "Astronomical Observations in the Irish Annals and their Motivation," *Peritia* 11 (1997): 1–43; Mark Williams, *Fiery Shapes: Celestial Portents and Astrology in Ireland and Wales, 700–1700* (Oxford: Oxford University Press, 2010).
45. Such criticisms were often made of work by Hubert H. Lamb and Gordon Manley (albeit while emphasizing their pioneering status): Astrid E. Ogilvie and Graham Farmer, "Documenting the Medieval Climate," in *Climates of the British Isles: Past, Present and Future*, ed. Mike Hulme and Elaine Barrow (London: Routledge, 1997), 112–34.
46. Rudolf Brázdil et al., "Historical Climatology in Europe: The State of the Art," *Climatic Change* 70 (2005): 363–430.
47. Francis Ludlow and Charles Travis, "STEAM Approaches to Climate Change, Extreme Weather and Social-Political Conflict," in *The STEAM Revolution: Transdisciplinary Approaches to Science, Technology, Engineering, Arts, Humanities and Mathematics*, ed. Armida de la Garza and Charles Travis (New York: Springer, 2019), 33–65.



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a study of ancient Egypt led jointly by a historian and a historical climatologist,[48] highlights the use of natural archives, quantification, and statistical modeling in pursuit of historians' questions concerning causality. Here, quantification of socio-economic activity alongside major historical events for one of ancient Egypt's most richly documented eras, the period of Ptolemaic rule from 305 to 30 BCE, made it possible to test new and long-standing hypotheses about the historical influence of hydroclimatic variability.

Egypt provides an excellent laboratory for the study of human-environmental relations, with its general lack of rainfall driving dependence on the Nile to compensate via irrigation and flood recession agriculture. This makes Egyptian society historically vulnerable to the hydroclimatic impacts of volcanic forcing. Loading of the stratosphere with sulfate aerosols from large explosive eruptions imposes short-term energy imbalances on the climate system due to modified reflection of the sun's radiation and can result not only in strong near-surface cooling on a hemispheric or global scale (the same mechanism at least partially responsible for severe Irish winters), but also related changes in the hydrological cycle. Instrumental data and climate modeling suggest that strong tropical eruptions tend to reduce global average precipitation (mainly via cooling that reduces evaporation), while eruptions in the higher latitudes of the northern hemisphere can reduce the north-south temperature contrast that drives the northward migration of moisture-bearing summer monsoonal winds. This is key for the Nile summer flood, as it is mainly fed by African monsoon rainfall over the Ethiopian Highlands. Before the construction of dams in the twentieth century, this monsoon rainfall would result in the Nile beginning to rise at Aswan on Egypt's southern border from early June. The highest levels were reached in August and September, with the water usually receding by the end of October, when sowing began.[49]

The Ptolemaic era was a watershed in Egyptian history that witnessed the establishment of a new political and economic framework, including a new capital at Alexandria—then one of the largest urban settlements in the Mediterranean world. Free-threshing wheat, comparatively vulnerable to drought, was one of the principal crops throughout Egypt during this period, serving the preferences of its Greek elite and a wider Mediterranean market.[50] New fiscal institutions, the issuing of coinage, and the development of banks and tax farming placed Egypt's

48. Joseph G. Manning et al., "Volcanic Suppression of Nile Summer Flooding Triggers Revolt and Constrains Interstate Conflict in Ancient Egypt," *Nature Communications* 8 (2017): https://doi.org/10.1038/s41467-017-00957-y.

49. Fekri A. Hassan, "Historical Nile Floods and Their Implications for Climatic Change," *Science* 212 (1981): 1142–45; Luke Oman et al., "High-Latitude Eruptions Cast Shadow over the African Monsoon and the Flow of the Nile," *Geophysical Research Letters* 33, no. 18 (2006): https://doi.org/10.1029/2006GL027665; Brian Zambri and Alan Robock, "Winter Warming and Summer Monsoon Reduction after Volcanic Eruptions in Coupled Model Intercomparison Project 5 (CMIP5) Simulations," *Geophysical Research Letters* 43, no. 20 (2016): 10920–28.

50. Joseph G. Manning, *The Last Pharaohs: Egypt Under the Ptolemies, 305–30 BC* (Princeton: Princeton University Press, 2010), 117–64.

already famous agricultural productivity under tighter control, allowing the state to extract more surplus from its territory.[51] Major wars with its main rival, the Seleukid kingdom in western Asia, dominated interstate politics during the third and second centuries BCE.[52] Generally regarded as the richest and most successful of the Hellenistic successor states to Alexander the Great's empire (and indeed comprising the longest single dynasty in Egyptian history), Ptolemaic Egypt was increasingly troubled from the end of the third century BCE, wracked with intermittent but increasing social unrest and facing pressure from an expanding Rome, continued animosity from its Seleukid rivals, and internal tensions associated at least partly with demographic growth.

In the study presented in figure 7, the link between Ptolemaic political and economic history and explosive volcanism was identified thanks to the integration of evidence from ice core-based volcanic forcing data, climate modeling, and ancient papyri and inscriptions. The authors began by comparing summer flood heights, recorded primarily at the famous Nilometer on Roda island near Cairo, with dates of explosive volcanism between 622 and 1902 CE, established through the study of ice cores. This revealed a persistent reduction of the summer flood following large tropical and extratropical eruptions, a result supported by analysis of climate model output showing drier conditions across the Nile basin after major twentieth-century eruptions (figs. 7a and 7b). To confirm that this volcanic flood suppression effect also occurred during the Ptolemaic period, qualitative indicators based on papyri and inscriptions were used to create annual flood-quality ranks on an ordinal scale and then analyzed.[53] Flood quality was indeed shown to tend toward lower ranks during volcanic years. This association between explosive volcanism and suppression of the agriculturally critical Nile summer flood thus makes it possible to hypothesize a plausible link between eruptions and major historical events in Ptolemaic Egypt.

The ability to compare the timing of repeated volcanic events with that of repeated historical events was also foundational to the study's approach, allowing the identification of statistically significant temporal associations across the Ptolemaic period. Due partly to the quality of the Egyptian documentation, the important uncertainties in dating that can hamper such analyses were minimized, while the history of volcanic forcing was derived from the recent synchronization of data from multiple ice cores.[54] Several kinds of recurring and datable historical events could thus be considered, including ten internal revolts against the

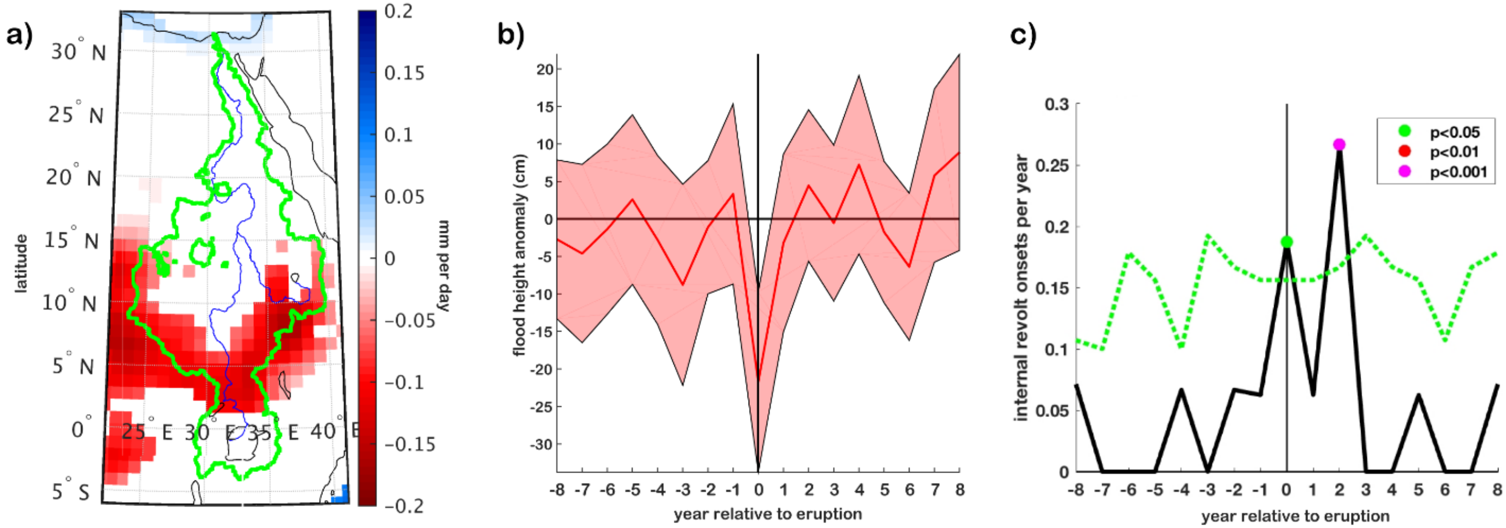
51. Ibid.

52. John D. Grainger, *The Syrian Wars* (Leiden: Brill, 2010).

53. These ranks were adapted from Danielle Bonneau, *Le fisc et le Nil. Incidences des irrégularités de la crue du Nil sur la fiscalité foncière dans l'Égypte grecque et romaine* (Paris: Éd. Cujas, 1971).

54. Michael Sigl et al., "Timing and Climate Forcing of Volcanic Eruptions for the Past 2,500 Years," *Nature* 523, no. 7562 (2015): 543–49; Matthew Toohey and Michael Sigl, "Volcanic Stratospheric Sulfur Injections and Aerosol Optical Depth from 500 BCE to 1900 CE," *Earth System Science Data* 9, no. 2 (2017): 809–31.

**Figure 7. The effect of volcanic eruptions on the Nile flood and the Ptolematic kingdom**




*Note: panel a): ensemble mean precipitation minus evaporation (P-E) response to five twentieth-century volcanic eruptions in CMIP5 (coupled model intercomparison project 5) model output. The response is the average P-E over the first summer season (May to October) that contained or followed the eruption, relative to the five summers preceding it. Only anomalies statistically significant at the 5% level are shown. The area within the green line is the Nile watershed. Panel b): annual Nile summer flood heights from the Islamic Nilometer composited relative to the ice core-estimated dates of eruption years for sixty large eruptions between 622 and 1902 CE (eruption years are represented at point 0 on the horizontal axis; years 1 to 8 then represent the eight years after these eruptions, and years -1 to -8 the eight years before). Shading indicates the 2-tailed 90% confidence interval, estimated using the t-distribution. Nile summer flood heights are on average twenty-two centimeters lower in eruption years ($P < 0.01$). Panel c): onset dates of internal revolt against Ptolemaic rule composited relative to the dates of sixteen volcanic eruptions (represented at year 0 on the horizontal axes; years 1 to 8 then represent the eight years after these eruptions, and years -1 to -8 the eight years before), excluding an eight-year buffer at the start and end of the period considered (305–30 BCE). Dots indicate statistically significant values estimated using Barnard's exact test. The green dashed line gives the 95% confidence threshold, also estimated using Barnard's exact test.*

*Source: figures and caption text adapted from Joseph G. Manning et al., "Volcanic Suppression of Nile Summer Flooding Triggers Revolt and Constrains Interstate Conflict in Ancient Egypt,"* Nature Communications *8 (2017): https://doi.org/10.1038/s41467-017-00957-y.*

Ptolemaic kings.[55] The onset of three of these coincided with eruption years, with another five occurring within the space of two years after an eruption (fig. 7c). The same holds for other kinds of events. Of the nine occasions on which Ptolemaic interstate warfare with the Seleukid kingdom ceased, three fell in an eruption year, with two others occurring within two years and one more within three years; two out of nine priestly decrees were issued in eruption years, with one more in the first year following an eruption. Finally, the sale of hereditary lands, long considered symptomatic of economic distress, with families usually averse to such transfers,[56] was also observed to spike upward, on average, for several years following eruptions.[57]

What is striking is thus the repeated coincidence between a small number of well-dated events: explosive eruptions, internal revolts and the likely related cessation of external military campaigning, attempts at reestablishing or maintaining political order through priestly decrees issued on behalf of the Ptolemaic kings, and an increased frequency of land sales.[58] It must be recognized that this suggestively close conjunction of events and eruptions could have occurred randomly. Nevertheless, the probability that the association between volcanic eruption dates and these events was entirely down to chance was examined, and the likelihood found to be low (at or considerably below 5% in all cases).[59]

To illustrate how statistical models can usefully inform historical research on past climate-societal interactions, it is worth briefly elaborating on the study's methodology. Consider the observed association between the onset of revolts against Ptolemaic rule, documented in papyri, and the dates of volcanic eruptions known from the polar ice cores. Even if these events were in reality unrelated, with no causal link between them, it would still be expected that an eruption would sometimes occur in the same year as a revolt, purely by chance. The relevant statistical question is, then, how unusual is the number of correspondences actually observed? Writing a probabilistic model for the number of correspondences to be expected if there were no real association between these events is straightforward. The authors conducted simulations that randomly reassigned each eruption to a new year between 305 and 30 BCE, then counted the number of correspondences

55. The dates of these ten revolts (or, more precisely, the dates of the beginning of potential revolts) were selected by Manning et al., "Volcanic Suppression of Nile Summer Flooding Triggers Revolt," following Anne-Emmanuelle Veïsse, *Les révoltes égyptiennes. Recherches sur les troubles intérieurs en Égypte du règne de Ptolémée III à la conquête romaine* (Leuven: Peeters, 2004).

56. Joseph G. Manning, *Land and Power in Ptolemaic Egypt: The Structure of Land Tenure* (Cambridge: Cambridge University Press, 2003).

57. Eighty-four sales dated with sufficient precision were identified. For more details, see Manning et al., "Volcanic Suppression of Nile Summer Flooding Triggers Revolt."

58. Allowing for some small uncertainties in revolt onset and eruption date. Experimentation with a fuller (though potentially less accurate) list of possible revolt onsets was also conducted and a statistically significant association still observed. See Francis Ludlow and Joseph G. Manning, "Revolts under the Ptolemies: A Paleoclimatological Perspective," in *Revolt and Resistance in the Ancient Classical World and the Near East: The Crucible of Empire*, ed. John J. Collins and Joseph G. Manning (Leiden: Brill, 2016), 154–71.

59. Manning et al., "Volcanic Suppression of Nile Summer Flooding Triggers Revolt."



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between revolt onset and the reassigned eruption dates, repeating this process a million times to build a random reference distribution.[60] Since the number of correspondences observed in reality exceeded the number of correspondences in 98% of these simulations, they concluded that there is a greater than 98% chance that a real association exists between revolt onset and explosive volcanic eruptions; in other words, that the association has not occurred randomly, and the observed correspondence is thus statistically significant at 98% confidence.

This testing of statistical significance supported the authors' argument for a causal link between explosive volcanism and revolt onset. The main causal pathway they propose hinges on the demonstrable hydroclimatic impact of volcanic eruptions on the Nile and the known heavy (if not complete) dependence of Egyptian agricultural productivity on its flood. The reduction in crop yields would then promote food scarcity, price increases, fear of starvation, difficulties in paying state-imposed taxes, land abandonment, and migration to urban areas in search of relief. Ultimately, this upheaval could result in revolts, particularly when certain background conditions—not least ongoing ethnic tensions between native Egyptians and Greek elites, or costly military mobilizations—added to the tension.[61] A finer understanding of the role of such conditions, which were certainly in flux over the nearly three centuries of Ptolemaic rule, remains to be achieved.

Alternative eruption-to-revolt pathways are also possible, either as primary or auxiliary causes underlying any given revolt. One hypothetical example would have eruptions disrupt Egyptian society through abrupt cooling that would reduce crop output and promote animal mortality; another through a dust-veil phenomenon favoring unrest associated with local religious interpretations—for instance if the dimming or discoloration of the sun's light were taken as signaling divine displeasure. Depending on the prevailing historical context, each causal link could be mitigated (or aggravated) by human action. For example, tax reductions, the imposition of food price ceilings, export bans, state granaries, and emergency grain imports might conceivably weaken the connection between reduced crop yields and increased social stress. It is important in this respect to note that not every volcanic event in the Ptolemaic period is associated with a revolt, and that Ptolemaic Egypt was by implication resilient to some volcanic hydroclimatic shocks.

A notable feature of social unrest in the period is the degree to which it varied in duration, extent, and severity. Some known periods of revolt seem to have touched the whole of Egypt and lasted twenty years, while others appear to have been more short-lived and localized. A simple explanatory model of unrest as a response to climate shocks cannot fully explain this variability. Might there be a correlation between the severity of climatic events and the intensity of the revolts? The scale of Nile flood failure, on some occasions causing only short-term local distress and at other times provoking multiple years of drought impacting

60. Ibid., 7.

61. Such background conditions, which can also be considered as making a "causal" contribution, act to make the association between explosive volcanism and revolt "probabilistically causal" rather than deterministic.



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the entire Nile valley and potentially leading to major famine, would likely have resulted in different scales of response. But evidence from the sources complicates this hypothesis: more localized flood failures may also have produced panic and fear as inhabitants recalled earlier episodes of crisis, as documented in the 238 BCE Canopus Decree.[62] In both scenarios, stress resulting from poor flooding can be hypothesized as an amplifier of existing ethnic tensions in certain parts of Egypt.[63] There is thus substantial scope for primary work on historical sources to complement historical-statistical approaches and enrich their interpretation. By returning to the documents, historians can further refine their understanding of the nature and scale of periods of social unrest in Ptolemaic Egypt, independently of the palaeoclimatic data. They can also consider their geographical resolution—topography may play a role in how vulnerable a particular area was to a reduction of the Nile flood by a given amount—and divide them into meaningful typologies in order to distinguish more fine-grained associations between historical events and hydroclimatic shocks.

Approaches such as those illustrated in the Irish and Egyptian examples remain comparatively rare in the broader field of environmental history.[64] We would argue, however, that these kinds of studies have much to offer, given the increasing focus on generating quantitative data and specialized methods to analyze them. In particular, they can open the field up to modes of reasoning characteristically reserved to the social sciences and applied to data-rich modern societies. Certainly, there are also limitations and concerns. As Aryn Martin and Michael Lynch have remarked, while "it is a simple practice when considered abstractly, in specific cases counting can be quite complicated, contentious, and socially consequential. Categorical judgments determine *what counts* as an eligible case, instance, or datum, and these judgments can be difficult and controversial."[65] In historical climatology, the categorization and quantification of historical information (especially qualitative information) is essentially and inherently reductive.[66] Some degree of nuance

62. Stefan Pfeiffer, *Das Dekret von Kanopos (238 v. Chr.). Kommentar und historische Auswertung eines dreisprachigen Synodaldekretes der ägyptischen Priester zu Ehren Ptolemaios' III. und seiner Familie* (Munich: K. G. Saur, 2004).
63. Ludlow and Manning, "Revolts under the Ptolemies."
64. For recent overviews of studies linking climate to society, which also consider concerns over environmental determinism, along with quantitative or statistical approaches, see Bas J. P. van Bavel et al., "Climate and Society in Long-Term Perspective: Opportunities and Pitfalls in the Use of Historical Datasets," *WIREs Climate Change* 10, no. 6 (2019): https://doi.org/10.1002/wcc.611; Fredrik Charpentier Ljungqvist, Andrea Seim, and Heli Huhtamaa, "Climate and Society in European History," *WIREs Climate Change* 12, no. 2 (2021): https://doi.org/10.1002/wcc.691.
65. Aryn Martin and Michael Lynch, "Counting Things and People: The Practices and Politics of Counting," *Social Problems* 56, no. 2 (2009): 243–66, here p. 243 (emphasis in the original).
66. This problem extends beyond historical climatology. For instance, in the context of the proliferation of *histoire sérielle* (quantitative history) in twentieth-century French historiography, several major figures remarked on the "impossibility of concluding" (*l'impossibilité de conclure*). This term was used by Bernard Lepetit in a review article

and context is inevitably lost when coding events or phenomena according to set categories that can never perfectly encompass all dimensions of an event, be it a drought, a famine, or anything else.[67]

There is no way to perfectly capture the relevant content of complex written evidence, but not everything must be quantifiable to legitimately employ this approach to "reading" a text, or, inversely, to allow nuance and contextual knowledge about a source's creation to inform quantitative analyses. Ultimately, the benefits of this approach, as illustrated in the Irish and Egyptian examples, are real. But for it to contribute to the fullest extent possible, it must be received in an open-minded way, with a balanced appreciation of its potential and its limitations and the understanding that it complements rather than competes with more established approaches in history.[68]

## Reinterpreting Textual Sources in Light of the Scientific Data

The two types of interdisciplinary practice described above focused on situations where the natural scientific data could in one way or another be complemented or enriched by additional information from the textual and material evidence that is usually the preserve of historians. The main difference between these approaches concerns the extent to which they apply quantitative methods and how they organize their reasoning as a result. In this section, we will look at two cases in which the direction of the intellectual inquiry goes the opposite way, that is, where the scientific data are used to interpret the textual evidence at the heart of the study. The first example deals with literary sources and focuses on late antique Italy; the second looks at documentary records and focuses on medieval Poland. In both cases, the availability of new palaeoclimatic or palaeoecological data has improved our understanding of written sources that historians have used for generations.

First, let us consider the example drawn from late antique Italy. Beginning in the 1980s, scientists connected natural archives suggestive of a powerful volcanic

from 1989, in which he refers to earlier quantitative historians such as François Furet, who had made the same observation two decades before: Bernard Lepetit, "L'histoire quantitative. Deux ou trois choses que je sais d'elle," *Histoire & mesure* 4, no. 3/4 (1989): 191–99, here p. 193. This observation resembles more recent critiques of the "cliometric" approach in economic history: see Francesco Boldizzoni, *The Poverty of Clio: Resurrecting Economic History* (Princeton: Princeton University Press, 2011). The cliometricians (economic historians focused solely on analyzing quantitative data from the past) have been accused of being inconclusive or at times forcing a priori theories on the historical evidence before analyzing the data itself.

67. In some instances, there is a fundamental ambiguity over whether a phenomenon should even be considered an "event" as opposed to a "process," with implications for how it should be best categorized or quantified.

68. A point well made concerning cliometrics and economic history by Joshua L. Rosenbloom, "The Good of Counting," introduction to *Quantitative Economic History: The Good of Counting*, ed. Joshua L. Rosenbloom (London: Routledge, 2008), 1–7, here p. 2.



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eruption in the mid-sixth century CE to contemporary written sources that appeared to record the subsequent atmospheric clouding.[69] Some argued that the climatic downturn associated with the eruption, known as the "536 event" for the year in which the aftereffects became noticeable, had a huge impact on societies across the entire northern hemisphere.[70] The insights made available by natural proxies, principally polar ice-core records and long-running dendroclimatological series, have encouraged a steady stream of studies revisiting and reinterpreting textual and archaeological sources in light of new environmental information.[71] Seemingly disparate historical texts have thus been collated together as witnesses to a climatic event, for which the palaeosciences provide additional context.

Debates concerning the scope and magnitude of the eruption's historical impact have been adjudicated almost entirely based on the palaeoscientific evidence,[72] with the textual sources receiving less attention.[73] However, a close reading of one famous source significantly alters the narrative framework associated with the event, all while remaining consistent with the climatic realities established by other disciplines. The longest known description of the 536 event is contained in the *Variae* of the official Cassiodorus (ca. 485–ca. 580), a collection of his correspondence while in the service of the Ostrogothic monarchy that ruled

69. Richard B. Stothers and Michael R. Rampino, "Volcanic Eruptions in the Mediterranean before AD 630 from Written and Archaeological Sources," *Journal of Geophysical Research* 88, no. B8 (1983): 6357–71, brought together and recontextualized four writers from the late antique Mediterranean, each of whom made incidental reference to strange climatic and meteorological disturbances that, when taken together, suggested the existence of a powerful volcanic eruption. Signs of post-eruption cooling in the tree-ring data were found by M. G. L. Baillie, "Dendrochronology Raises Questions about the Nature of the AD 536 Dust-Veil Event," *The Holocene* 4, no. 2 (1994): 212–17. Apparent dating discrepancies were resolved in Sigl et al., "Timing and Climate Forcing of Volcanic Eruptions." For a recent overview, see Newfield, "The Climate Downturn of 536–50," 452–63.
70. Though not all scholars agree with this interpretation. See Joel D. Gunn, ed., *The Years without Summer: Tracing A.D. 536 and Its Aftermath* (Oxford: Archaeopress, 2000); Büntgen et al., "Cooling and Societal Change during the Late Antique Little Ice Age"; Kyle Harper, *The Fate of Rome: Climate, Disease, and the End of an Empire* (Princeton: Princeton University Press, 2017).
71. Stothers and Rampino, "Volcanic Eruptions in the Mediterranean before AD 630." A global perspective on the eruption, from Yucatán to China, is found in the papers collected in Gunn, *The Years without Summer*: without the volcanic framework, there would be little to tie together such varied subjects as Roman epistolography and Mayan hydraulics. Cassiodorus's account of the 536 event is discussed in both its climatic and philosophical contexts in Harper, *The Fate of Rome*, 251–52, with a broader discussion of the event at pp. 249–59. The bibliography on the 536 event is both vast and steadily accumulating. For more references, see recent works by Kyle Harper and Timothy Newfield.
72. Samuli Helama, Phil D. Jones, and Keith R. Briffa, "Dark Ages Cold Period: A Literature Review and Directions for Future Research," *The Holocene* 27, no. 10 (2017): 1600–606; Helama, Jones, and Briffa, "Limited Late Antique Cooling," *Nature Geoscience* 10, no. 4 (2017): 242–43; Haldon et al., "Plagues, Climate Change, and the End of an Empire."
73. An exception is Antti Arjava, "The Mystery Cloud of 536 CE in the Mediterranean Sources," *Dumbarton Oaks Papers* 59 (2005): 73–94.

Italy between 493 and 553.[74] At first reading, the letter supports a catastrophist interpretation. We are told that the sun has lost its usual brightness and that temperatures have been cool for nearly an entire year.[75] The seasons themselves have been thrown into disarray: "we have had winter without storms, spring without mingled weather, summer without heatwaves."[76] Realizing that crops could not grow under such conditions, Cassiodorus orders a subordinate to open state granaries to stave off imminent famine.[77]

Though this appears to be a powerful image of the unrelenting power of climate over premodern society, it should not be taken at face value. The many descriptions of environmental disasters found in Cassiodorus's writings are sometimes pulled directly from earlier accounts of similar anomalies. His observation that the strange clouding lasted "almost a full year" echoes word-for-word Pliny the Elder's account of the sole other recorded example of prolonged solar dimming,[78] in the aftermath of Julius Caesar's assassination in 43 BCE.[79] Another element of Cassiodorus's striking description—how "air laden with snow … blocks the heat of the sun and deflects the view of human frailty"[80]—has a parallel in a second well-known account of Caesar's comet found in Plutarch's *Life of Caesar*: "heat came to earth only faintly and ineffectually, so that the air hung dark and thick on the earth because of the lack of radiance to penetrate it."[81] That such intertextual allusions were common stylistic hallmarks of Roman literature serves as a warning against treating these statements uncritically.

Identifying how the 536 eruption impacted Italy's climate and society with any precision then becomes an impossible task, and we are left with the generalizing observation that environmental oddities of some sort were noticeable

74. Cassiodorus, *Variae* 12.25; for an English translation, see *The* Variae*: The Complete Translation*, trans. M. Shane Bjornlie (Oakland: University of California Press, 2019), 493–95. On the historical and literary contexts, see M. Shane Bjornlie, *Politics and Tradition between Rome, Ravenna and Constantinople: A Study of Cassiodorus and the* Variae*, 527–554* (Cambridge: Cambridge University Press, 2013).

75. Cassiodorus, *Variae* 12.25.2.

76. Cassiodorus, *Variae* 12.25.3 (trans. *The* Variae, 494).

77. Cassiodorus, *Variae* 12.25.6.

78. Cassiodorus, *Variae* 12.25.2 (trans. *The* Variae, 494); Pliny the Elder, *Natural History* 2.98. Note the exact matches in the Latin for Cassiodorus ("Quod non eclipsis momentaneo defectu, sed *totius paene anni* agi niholiminus constat excursu") and Pliny ("Fiunt prodigiosi et longiores solis defectus, qualis occiso dictatore Caesare et Antoniano bello *totius paene anni* pallore continuo").

79. On Caesar's comet, see John T. Ramsey and A. Lewis Licht, *The Comet of 44 B.C. and Caesar's Funeral Games* (Atlanta: Scholars Press, 1997). Similar to the 536 event, the climatic disturbances of 43 BCE were likely the result of a volcanic eruption, possibly the Okmok volcano in Alaska's Aleutian Islands; see Joseph R. McConnell et al., "Extreme Climate after Massive Eruption of Alaska's Okmok Volcano in 43 BCE and Effects on the Late Roman Republic and Ptolemaic Kingdom," *Proceedings of the National Academy of Sciences* 117, no. 27 (2020): 15443–49.

80. Cassiodorus, *Variae* 12.25.5 (trans. *The* Variae, 494).

81. Plutarch, *Caesar* 69.4; trans. Christopher Pelling, *Plutarch: Caesar* (Oxford: Oxford University Press, 2011), 128.



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at this date. Reconstructions of past climatic events and processes should be assessed using the scientific evidence. The use of historical texts, especially those rich in rhetoric and artifice, for this purpose is a flawed enterprise because they rarely specify the duration, scope, or magnitude of the phenomena they describe. However, our interpretation of these texts is enriched through the addition of information that can only be derived from the palaeosciences. The intertextual references in Cassiodorus's description, for instance, are in fact an effort to transform the unprecedented into the legible using a framework familiar to Roman literary culture. To date, most of the new interdisciplinary research has focused on understanding climate's impact on human populations. We should also ask how the authors of our sources engaged with climate, and the study of the literary sources may be one of the best ways to do that.

The second case that we want to present shows that focusing on documentary rather than literary sources—that is, on texts a priori devoid of the (potentially misleading) intertextuality apparent in Cassiodorus—leads to a similar conclusion. This example concerns Greater Poland (*Wielkopolska*), the cradle of the Polish state, established in the second half of the tenth century CE and for a long time one of the most economically developed, populous, and richest regions in the country. The economic history of Greater Poland (and Poland as a whole) has been the subject of many studies, especially concerning the early modern period. Nevertheless, one of the primary obstacles remains the limited number of written sources. Administrative records such as tax registers or estate inventories only appear in the sixteenth century. The availability of documentation for the early Middle Ages is particularly limited: though an inventory of archaeological excavations of early medieval material in Greater Poland does exist, it tends to focus on proto-urban centers, despite the fact that the dominant forms of economic activity in the region were agriculture and livestock farming.[82]

To reconstruct the network of medieval rural settlements and the state of the rural economy, historians have thus relied on one particular kind of source, the "location privileges." These charters recorded the rules governing relationships between landlords and peasants and were issued from the thirteenth century, when German colonization began in Greater Poland.[83] Recent research has established the fourteenth century as the key period in this process, and charters from that time record a significantly larger number of existing and newly established villages.[84] As a result, it has become commonplace to argue that the network of rural settlements

82. Archaeologiczne Zdjęcie Polski, http://www.nid.pl; Ryszard Mazurowski, *Metodyka archeologicznych badań powierzchniowych* (Warsaw: Państ. Wydaw. Naukowe, 1980).
83. Jan M. Piskorski, "The Medieval Colonization of Central Europe as a Problem of World History and Historiography," in *The Expansion of Central Europe in the Middle Ages*, ed. Nora Berend (London: Routledge, 2017), 215–36.
84. Teodor Tyc, *Początki kolonizacji wiejskiej na prawie niemieckim w Wielkopolsce (1200–1333)* (Poznań: Drukiem K. Miarki, 1924); Konstanty Jan Hładyłowicz, *Zmiany krajobrazu i rozwój osadnictwa w Wielkopolsce od XIV do XIX wieku* (Lviv: Kasa im. Rektora J. Mianowskiego, 1932); Karol Stefański, "Wsie na prawie niemieckim w Wielkopolsce w latach 1333–1370," *Roczniki Historyczne* 37 (1971): 1–36.



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in Greater Poland—which, with its regular layout of fields and placement of houses, has in some areas survived until today—was a consequence of changes that took place during the thirteenth and fourteenth centuries.[85] Villages were transferred to German law, and the farming methods used on the surrounding lands modernized at the same time.

However, although these location privileges created a kind of legal reality, we must recognize that they actually represent no more than the plan or intention to establish a new village or to modernize an existing one. They should not be taken as proof that such plans were immediately or indeed ever implemented.[86] Moreover, primary sources of this kind do not record the chronology of a village's demographic and economic development, nor even moments of crisis; all they do is document relevant legal actions. The inherent limitations of these sources have long been an obstacle to understanding the dynamics of Greater Poland's medieval economic transformation. Yet this impediment can be overcome by using environmental archives and conducting joint historical-environmental research.

A recent historical-palaeoecological project carried out in Greater Poland has taken the form of micro-studies, with high-resolution multi-proxy palaeoecological research conducted on the basis of material extracted from the region's peat bogs.[87] Focusing on breakthrough moments in its political and economic history, integrating historical and environmental archives, and mobilizing both humanistic and scientific research methods, this study has altered our understanding of the course of late medieval colonization in the region. Notably, the frequency of the radiocarbon dates obtained (more than one per century) made it possible to better grasp the dynamics of the colonization processes. The analysis of environmental data revealed that the shift to German law evoked in the written sources was less dynamic than historians once argued, and probably followed a different, far longer chronology than was previously thought. Palynological data show not only a gradual deforestation, but also a similarly gradual increase in the proportion of pollen from cultivated plants, notably cereals (fig. 8).

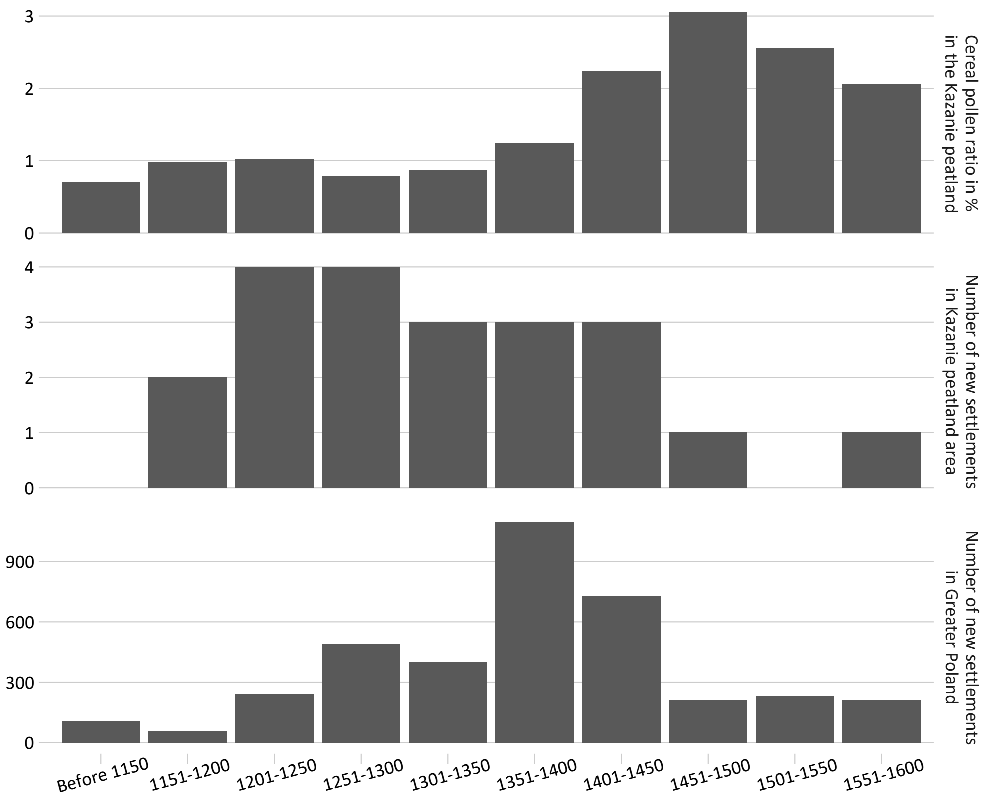
The Kazanie peat bog in central Greater Poland is a good example of such slow, progressive development. Although most of the settlements around the site were established or reorganized according to German law in the thirteenth and fourteenth centuries, a significant increase in human economic activity resulting from the development of agriculture can be observed only from the fifteenth century. It was at this point that the population increased noticeably and farming methods were probably

85. Antoni Gąsiorowski, "Krajobraz naturalny i rozwój osadnictwa. Organizacja społeczna i rozwój gospodarstwa wiejskiego," in *Historia Wielkopolski do roku 1795*, ed. Jerzy Topolski (Poznań: Wydawnictwo Poznańskie, 1969), 254–61, here p. 256.

86. Stanisław Kuraś, *Przywileje prawa niemieckiego miast i wsi małopolskich XIV–XV wieku* (Wrocław: Instytut Historii Polskiej Akademii Nauk, 1971), 111.

87. Sambor Czerwiński et al., "Environmental Implications of Past Socioeconomic Events in Greater Poland during the Last 1200 Years: Synthesis of Paleoecological and Historical Data," *Quaternary Science Reviews* 259 (2021): https://doi.org/10.1016/j.quascirev.2021.106902.

**Figure 8. Development of rural settlement in Greater Poland**




*Note: the upper panel is based on pollen analysis data; the center and lower panels on data from location privilege charters. The middle panel reflects the number of new settlements in the immediate vicinity of the site shown on the upper panel, namely the Kazanie peat bog, near Pobiedziska in Greater Poland; the lower panel shows data for the entire Greater Poland region.*
*Source: based on Konstanty Jan Hładyłowicz,* Zmiany krajobrazu i rozwój osadnictwa w Wielkopolsce od xiv do xix wieku *(Lwów: Kasa im. Rektora J. Mianowskiego, 1932), 109–227; Sambor Czerwiński et al., "Znaczenie wspólnych badań historycznych i paleoekologicznych nad wpływem człowieka na środowisko. Przykład ze stanowiska Kazanie we wschodniej Wielkopolsce,"* Studia Geohistorica *7 (2019): 59 and 63; Czerwiński et al., "Environmental Implications of Past Socioeconomic Events in Greater Poland during the Last 1200 Years: Synthesis of Paleoecological and Historical Data,"* Quaternary Science Reviews *259 (2021): https://doi.org/10.1016/j.quascirev.2021.106902, p. 8.*

modernized via the introduction of the three-field system, more advanced tools such as the plow and iron harrow, and a new pattern of field organization. Only at the end of the fourteenth century does the share of cereal pollen in the samples collected for the study permanently exceed 1%, before growing over the fifteenth century to reach 3%. This means that the colonization which began in the thirteenth and fourteenth centuries did not entail large groups of settlers. The newly established



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or modernized villages were relatively small, with a demographic and economic potential that increased slowly over a long period of time to reach a peak in the sixteenth century.[88]

Supplementing the existing base of written documentation with environmental sources thus results in a substantial revision of the traditional historiographical vision of German colonization: the palaeoenvironmental data show a more gradual pace of rural expansion in Greater Poland, based to a large extent on natural demographic growth. As with the Latin literary texts discussed above, incorporating natural scientific data can either lead to a completely new interpretation of the written sources or substantiate one existing argument at the expense of others—some of which have been developed over decades and long persisted in historical scholarship. There is no doubt that as the precision and versatility of the palaeoscientific data grows, we will gain a more comprehensive and solid understanding of the past. It is to be hoped that the methodological and practical perspectives offered in this article will precipitate and facilitate this process.[89]

## Constructing Historical Narratives in Heterodisciplinary Environments

In his 1967 monograph, *Histoire du climat depuis l'an mil*, Le Roy Ladurie concluded that over the long term the human consequences of climate seemed to be slight and difficult to detect.[90] Now, after more than fifty years of research, we know that this statement was overly skeptical or at least reductionist, tending toward anthropocentric solipsism. In fact, Le Roy Ladurie was wary of the simplistic interpretations that might be attributed to his work. Over thirty years later, when the global climate crisis directed public and scholarly attention back to climate's role in human affairs, the same author formulated a stronger case for the role of climatic variability in human history in his three-volume *Histoire humaine et comparée du climat*, published in 2004.[91] In a way, this was a return to the positions held by the generation of historians active in the first decades of the twentieth century, such as

88. Czerwiński et al., "Environmental Implications of Past Socioeconomic Events." Note that the same research team has demonstrated that large-scale colonization with a profound ecological impact could also occur within one generation, in special circumstances when the financial and institutional capacities were available. See Mariusz Lamentowicz et al., "How Joannites' Economy Eradicated Primeval Forest and Created Anthroecosystems in Medieval Central Europe," *Scientific Reports* 10, no. 1 (2020): https://doi.org/10.1038/s41598-020-75692-4.

89. Another recent example of a similar approach is Martin Bauch, "Die Magdalenenflut 1342 am Schnittpunkt von Umwelt- und Infrastrukturgeschichte," *NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin* 27, no. 3 (2019): 273–309.

90. Emmanuel Le Roy Ladurie, *Histoire du climat depuis l'an mil* (Paris: Flammarion, 1967); Le Roy Ladurie, *Times of Feast, Times of Famine*.

91. Emmanuel Le Roy Ladurie, *Histoire humaine et comparée du climat*, 3 vols. (Paris: Fayard, 2004–2009).



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Ellsworth Huntington in the United States or Franciszek Bujak in Poland.[92] More generally, however, this shift shows the tensions faced by historians who decide to write about the "natural" aspects of history, not least the ready ideological master narratives into which one can easily be subsumed, even against one's will.

In most studies relating to climate, the master narrative that comes to the fore depends on which humanistic or natural scientific discipline is predominant in the analysis.[93] To understand what is at stake in this struggle to define the master narrative, it is worth discussing briefly the main rhetorical tropes that dominate the emerging field of interdisciplinary environmental history, applying Hayden White's schema of metaphor, metonymy, synecdoche, and irony to the environmental context.[94] Until recently, the catastrophism and determinism that served as the main rhetorical trope in climate change history was something of a *metonymy*. Its reductionist representation of reality focused on a single cause to promote a simple mechanistic argument, ultimately deploying a story dominated by a tragic plot. Such stories usually have the radical intention of shaking their readers' consciousness and encouraging them to take action.[95] This is why, despite their ability to mislead by streamlining the past and their fixation on a tragic ending, catastrophism and determinism are not without merit. They can be deployed in historical narratives to motivate human action, and it is no surprise that such master narratives tend to prevail in stories authored by natural scientists. In the end, it is they who are most acutely aware of environmental change and of the severity of the environmental crisis we are approaching.[96]

Of course, metonymy-catastrophism is just one of the multiple tropes available to historians (White described four, but emphasized that there are probably more). A mature field of research such as environmental history, therefore, should not restrict itself to a single trope, a unique narrative arc for recounting the past. At present, the most favored alternative master narrative is "resilience," something of an *irony*, if not a *synecdoche*, in White's terms. Synecdoche is characterized by an integrative mode of representation that uses the part to consider the whole (resilience accounts aim to present holistic perspectives based on specific examples). It combines an organicist argument (emphasizing the unity rather

92. Ellsworth Huntington, *Civilization and Climate* (1915; New Haven: Yale University Press, 1924); Franciszek Bujak, *Nauka, społeczeństwo, historia* (Warsaw: Państ. Wydaw. Naukowe, 1976).

93. As discussed in Adam Izdebski et al., "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 (2016): 5–22.

94. Hayden White, *Metahistory: The Historical Imagination in Nineteenth-Century Europe* (Baltimore: Johns Hopkins University Press, 1973).

95. Ibid.

96. Of course, such approaches have made their way into the discipline of history, where they have attracted much public attention. See, for instance, Ronnie Ellenblum, *The Collapse of the Eastern Mediterranean: Climate Change and the Decline of the East, 950–1072* (Cambridge: Cambridge University Press, 2012); and in particular Harper, *The Fate of Rome*.

than conflict of society and nature) and a conservative ideology (resilience is often used to reinforce neoliberal policies by invoking humanity's capacity to "bounce back"). Unsurprisingly for a synecdoche trope, whose basic "emplotment" is comedy (ending on a positive note), resilience narratives tend to be cautiously optimistic. This optimistic tone can make even their authors feel uncomfortable in the context of global climate change, and studies that foreground these narratives often include admonitory notes about not taking their optimism too far or underestimating the seriousness of the planetary crisis.

Resilience has emerged within scholarly discourse as one method for assessing the impacts of climate and climatic variability on human populations past and present, migrating from an original definition that focused first on engineering and then on ecological systems.[97] At its heart, it attempts to measure a system's durability and stability in the face of various stressors that threaten its equilibrium: the system's resilience is its "resistance to change."[98] In environmental history, the concept has most often been used to study climate's impact on the state and socioeconomic institutions of past societies at varying levels, from the empire to the village,[99] notably in terms of the decline and formation of states, agricultural productivity, settlement patterns and density, and so forth. Resilient societies were able to weather the storms, as it were, and adapt to new realities while maintaining their fundamental social attributes (as defined by the modern observer-researcher). Despite the place

97. For resilience's origins within ecology, see C. S. Holling, "Resilience and Stability of Ecological Systems," *Annual Review of Ecology and Systematics* 4 (1973): 1–23. On the utility of resilience applied to human societies, see Carl Folke, "Resilience: The Emergence of a Perspective for Social-Ecological Systems Analyses," *Global Environmental Change* 16, no. 3 (2006): 253–67.

98. There are many definitions of resilience, but "the tendency to understand resilience as resistance to change is ubiquitous in the literature": Lennart Olsson et al., "Why Resilience Is Unappealing to Social Science: Theoretical and Empirical Investigations of the Scientific Use of Resilience," *Science Advances* 1, no. 4 (2015): http://dx.doi.org/10.1126/sciadv.1400217, here p. 2.

99. *Inter alia*, see Adam Izdebski, Lee Mordechai, and Sam White, "The Social Burden of Resilience: A Historical Perspective," *Human Ecology* 46, no. 3 (2018): 291–303; Elena Xoplaki et al., "Modelling Climate and Societal Resilience in the Eastern Mediterranean in the Last Millennium," *Human Ecology* 46, no. 3 (2018): 363–79; Xoplaki et al., "The Medieval Climate Anomaly and Byzantium: A Review of Evidence on Climatic Fluctuations, Economic Performance and Societal Change," *Quaternary Science Reviews* 136 (2016): 229–52; Xoplaki et al., "Hydrological Changes in Late Antiquity: Spatio-Temporal Characteristics and Socio-Economic Impacts in the Eastern Mediterranean," in *Climate Change and Ancient Societies in Europe and the Near East: Diversity in Collapse and Resilience*, ed. Paul Erdkamp, Joseph G. Manning, and Koenraad Verboven (Cham: Palgrave Macmillan, 2021), 533–60; Tamara Lewit, "A Viewpoint on Eastern Mediterranean Villages in Late Antiquity: Applying the Lens of Community Resilience Theory," *Studies in Late Antiquity* 4, no. 1 (2020): 44–75. A 2018 special issue of the journal *Human Ecology* was devoted to the question of historical resilience in the face of climatic strain; see John Haldon and Arlene Rosen, "Society and Environment in the East Mediterranean ca. 300–1800 CE: Problems of Resilience, Adaptation and Transformation; Introductory Essay," *Human Ecology* 46, no. 3 (2018): 275–90.



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catastrophism has held in natural scientific publications on climate history and in popular environmental history books, it has never completely dominated: structuralist interpretations of the relationship between the environment and human history, akin to resilience theory, are some of the most enduring within the field, stretching back to Le Roy Ladurie's first publications.[100] Though they avoid the declensionist tendencies common to metonymy-catastrophist narratives, synecdoche-resilience narratives nonetheless perpetuate the idea that climate acts and humans respond to it. Even successful adaptations and ameliorations are still reactions to outside stimuli. To date, most interdisciplinary research has thus focused on understanding climate's impact on human populations.

The humanities and social sciences have nevertheless put forward a strong philosophical critique of socio-ecological resilience, in particular how it serves to defend the neoliberal status quo. In a resilience narrative, action seeks to strengthen existing systems so that they can better survive environmental crises, rather than to change the systems that provoked those crises in the first place. Past precedents of resilient societies (based on historical analysis) should not be used to legitimize an enduring socioeconomic regime that endangers life on earth. As soon as one recognizes that neoliberalism is the dominant ideology of the contemporary globalized world, metanarratives of resilience and their optimistic use of synecdoche (in which the different parts of a system can survive environmental crisis) can be seen for what they are: a conservative position (maintaining the existing order) rather than a liberal one (unconcerned by people affected by climatic and environmental changes). This is yet another reason why resilience narratives should not be privileged unquestioningly in the field of interdisciplinary environmental history, despite the repeated calls to move away from catastrophist narratives.[101]

Ultimately, we should reject neither metonymy-catastrophism nor resilience-synecdoche narratives, but rather work to expose the strengths and weaknesses of each and continue experimenting with their application to produce a truly interdisciplinary environmental history. The more aware the field becomes of its theoretical and rhetorical entanglements, the easier it will become to blend tropes, invent new ones, and carry across a socially powerful and intellectually insightful message that is needed in our times.

To conclude, we wish to emphasize that the interdisciplinary environmental history proposed in the preceding pages does not displace the role or function of the traditional historical narrative. Instead, we would simply argue for the incorporation of different types of evidence—and their interpretation—when they are relevant. As demonstrated in this article, the relevance of the palaeosciences is surprisingly wide and encompasses nearly every type of historical question.

100. Le Roy Ladurie, *Times of Feast, Times of Famine*.
101. The most recent examples are van Bavel et al., "Climate and Society in Long-Term Perspective"; and Charpentier Ljungqvist, Seim, and Huhtamaa, "Climate and Society in European History."

The main challenges to this incorporation remain practical and theoretical rather than financial. While many socio-environmental research questions do indeed require larger-scale projects with funding from national or European research agencies, several groundbreaking studies have emerged through grassroots networking and collaboration. Most of the case studies presented in this article, for example, were prompted by a geologist producing interesting data and then seeking out a historian to help contextualize it. The real obstacles to this interdisciplinarity more often lie within our own field. The traditional academic structures of history as a discipline are not accustomed to researchers moving across periods and regions, trying to harness the expertise of entire teams in order to tackle socio-environmental research questions. Although the discipline as a whole is proud of such undertakings, which prove its vigor and relevance to a wider public, often its practitioners prefer to stay within their "tribal" structures and tacitly reject the new academic habits and values, the openness that is the prerequisite of interdisciplinary history. Those scholars firmly entrenched in history, used to being in control of both the narrative and the data, often do not value the teamwork that leads to joint publications in which it is the synergy of several authors that creates intellectual value, rather than the well-demarcated contribution of an individual. If the discipline of history, and particularly the field of preindustrial environmental history, is to avoid becoming dated or slipping into a kind of antiquarianism, it must openly confront the issues of co-authorship and collaboration in teams with mixed expertise—already current in the natural sciences or even history's sibling, archaeology. For that, perhaps the surest way forward is to reorient how we educate and train those historians interested in the environment who need exposure to the relevant natural sciences. They must learn how to handle both the written sources and the natural scientific data with care. With the flourishing of different approaches to the past, history as a discipline—and as an intellectual adventure—has a great future ahead of it.

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