An Environmental and Climate History of the Roman Expansion in Italy

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Recent years have seen a considerable increase in the sophistication of the tools used to study the environmental and climate histories of past societies. Significant advances have been made not only in the science of paleoclimatology or environmental archaeology, but also in relevant practices of historical inquiry. Sparked in no small part by contemporary discussions of climate change and the anthropocene, a first wave of research over the last two decades focused on moments of abrupt climate change and societal transformation. For the ancient Mediterranean, this has meant intense interest in climate's possible role in the disintegration of the Roman Imperial state. At the same time, the broader study of past climate and societies increasingly includes reconstructions less focused on isolated catastrophes and more interested in longer term, often subtle dynamics of human responses to climatic and environmental variability. This emergent field of "historical climate studies" remains impressive for its disciplinary consilience and desire to combine the efforts of scientific, social scientific, and humanistic researchers. Indeed, the turn towards more diachronic histories of human relationships with the environment can be seen to result precisely from advances across different disciplines. As scientific methods grow more refined, and as we assemble a richer corpus of historical and archaeological data, we become better positioned to combine our results to reconstruct past climate and landscape beyond and between those punctuated moments of abrupt change or catastrophe that first attracted attention.[1]

This paper contributes to the emergence of this more expansive field of historical climate studies by extending discussion of Italy's climate and environmental history to a period that has so far attracted little attention, despite clear reasons for interest. We hope to lay the groundwork here for an environmental and climate history of Italy in the period of Rome's imperial expansion in the peninsula during the second half of the last millennium BCE. Over this period, Roman expansion drove the transformation of Italy first militarily, and then progressively in cultural, political, and economic terms. In 400 BCE, Rome was the largest of the Latin-speaking cities of western Central Italy. Roman political power was initially monopolized by a narrow group of religiously privileged, landowning families known as patricians. Legal reforms in the fourth century BCE broke that domination and created a more open patricio-plebeian elite (or *nobilitas*), whose membership drew from a wider pool of landowning families. Accompanying this change was a process of state creation and the intensification of state-directed warfare. From the mid-fourth to the third centuries BCE, Rome's legions extended control over Latium and then progressively across the peninsula. Romans encountered a landscape occupied by heterarchical communities with highly varied political and cultural structures, often associated with different ecological niches. Urban societies of Magna Grecia and Etruria occupied coastal plains or river valleys offering access to arable land and maritime trade routes. Upland areas of the Apennines saw less urbanized Sabines and Samnites, while societies along the east coast participated in the cultural and economic circuits of the Adriatic world. By the mid-second century BCE, Rome conquered all the way to the Alps, defeating Ligurians, Gauls, and other groups closely linked to Iron Age cultures of Transalpine Europe. Rome's approach to each area differed, variously including extensions of citizenship, colonization programs, or seizures of territory as state property (*ager publicus*). However, Rome showed little interest in controlling domestic affairs in local communities, and archaeology reveals considerable cultural continuity from Pre-Roman to Roman phases in many places into the first century BCE.[2]

Imperial expansion in Italy accompanied demographic, economic, and political developments. At the time of Rome's early expansion, settlement in the Italian countryside grew denser, a process referred to as rural infilling and discussed below. Extensive urbanization commenced in Italy around 300 BCE. The increase in urban population was most evident in the city of Rome itself, which relied on improved access to grain from conquered areas like Sicily, Sardinia, and North Africa to feed a population approaching one million residents by the later first century BCE. On the economic front, Rome was a late adopter of coinage, but by the second century BCE drove a unified monetary zone across Italy. Slavery became entrenched at the core of the productive economy. Expansion accompanied increased trade around Italy and radiating outward into the Mediterranean. A state apparatus developed to manage and exploit the Mediterranean Empire, with wealth and slaves flowing to Italy as its core. The cumulative effect of all these trends was the eventual integration of Italy along sociocultural, economic, and political lines. By the time Augustus established the principate in 29 BCE, the diverse societies of Iron Age Italy appeared transformed into what ancient sources referred to as "United Italy" (*tota Italia*).[3]

There has been intense debate over the character of early Roman imperialism. Recent work challenges ideas of Roman exceptionalism or any exclusively Roman ideology conditioning initial imperial success in the fourth and third centuries BCE. In this period, competition between Rome and Italian rivals took place amid geopolitical transformations sweeping over much of the Central Mediterranean. This embedding of Roman expansion within broader trends shifts scholarly focus from Rome's intrinsic characteristics to more general and extrinsic forces such as ecology and climate, among others. In precapitalist societies like those of Pre-Roman and Roman Italy, rural production drove the economy, and an understanding of the countryside is essential to knowing how these societies functioned and developed. Additionally, empire itself, as an extension of power over territory, was intimately connected with landscape. There are specifically Roman aspects here, as Roman expansion in Italy involved attempts to reclassify land as state property, while Roman citizenship was from an early date ordered around landholding. The fundamental importance of landscape, combined with the ecological dimensions of Roman imperialism, represent our main impulses to study the dynamics of climate and environment in this period. With that said, our goal is not to replace the massive literature on early Roman imperialism with a simplistic narrative of environmental determinism. None of the authors of this paper would argue that Roman Italy resulted from environmental or climatic change. What we do all agree on is that the dynamic natural world mattered in important if complex ways at this formative moment of Italy's history and that these complexities remain insufficiently explored.[4]

The moment seems right for a first synthesis of the environmental and climate history of the earlier period. The quality and quantity of available scientific evidence has changed considerably. A desire to bring scientific data to bear on the history of Roman expansion is not new. Already in 1962, John Bryan Ward-Perkins made pioneering use of pollen records from Lago di Bracciano to test ancient accounts of Republican Rome's armies encountering the supposedly pristine Ciminian forest of South Etruria to the lake's north. More than a half century later, evidence from multiple lakes in the region and better calibrated dating methods offer better possibilities for reconstruction. Change in the scientific data can be detected even over the last several years. Publication of data relevant to first-millennium BCE Italy increases at a welcome pace.[5]

Another reason for turning to the period of Roman expansion is the opportunity to tackle some relatively untested ideas about the relationship between state formation and environment. Thus far, the study of Roman climate has been dominated by a focus on climate change's role in Late Imperial history. In the intense debate over climate's role in the Empire's disintegration, there starts to appear an implication that the earlier period's climate was more stable and by extension more conducive to state formation. This view has not really been confronted in explicit terms, although it often emerges implicitly with references to the coincidence of the end of the Empire with the close of a climate period referred to as the "Roman Warm Period" (RWP) or "Roman Climate Optimum" (RCO). In this way, the RWP or RCO comes to be understood not only as a period of past climate but in historical terms as an ingredient in Rome's earlier imperial success. To date, little focused attention on either the period's parameters or its historical implications means that the RWP appears inconsistently in both scientific and historical literature. There is no consensus on the timing of its onset with dates suggested anywhere from 550 to 200 BCE, or even as late as 1 BCE. There has also been little explicit consideration of exactly how a RWP supported Roman imperialism. We might imagine, for example, a view that climate was stable enough to fade into the background, granting room for social development. Otherwise, we might assign a more active role to the RWP by increasing marginal returns on agricultural labor, by allowing for more extensive cultivation, by facilitating more reliable maritime redistribution, or by facilitating demographic expansion. These or other historical models remain to be tested, and they promote our interests in the earlier period.[6]

This paper presents the results of a collaboration between historians, archaeologists, and scientists to address these ideas and, for the first time, contextualize them within an environmental and climate history of the early stages of Roman empire-making in Italy. In the first half of this paper, we present a first synthesis of current knowledge of the environment and climate of Central Italy and neighboring regions that formed the focus of early Roman imperialism, looking at scientific archives for climate, pollen data, and historical archives. This review shows that there were relatively few short-term extreme climate shifts during the main period of Roman expansion. Global indices reflect a period of warmer and probably wetter overall climate commencing around 300-200 BCE. However, there remained considerable variability in the local expression of these trends. Meanwhile, owing to Italy's Mediterranean climate, inherent short-term variability in the region persisted. As a guide for historical interpretation, the idea of an RWP feels overly simplifying.

If this diminishes the usefulness of the RWP to historical research, we do not dispute the role of climate and environment in state-formation and economic development during the period. Instead, the second half of this paper intends to shift the focus from climate as an external driver to the human agency and societal resilience that mediated it. Drawing upon an array of archaeological and historical approaches, we propose that the history of Italy's climate and environment is best studied within the sprawling matrix of practices by which communities and households mitigated risk. Wide-ranging discussion intends to showcase the diverse methodologies now available for the study of the ways in which Italians developed environmental resilience. Resilience is the ability of a system to withstand disturbance, and substantial recent discussion considers the applicability of concepts drawn from resilience theory to past human-environmental relationships. All the elements of this theory—resilience, disturbance, and system—are historically specific, and we argue that available evidence from our period puts us in the fortunate position to offer a historicized discussion of the interplay between environmental resilience and empire-making.

In this regard, the paper's overall goal is to advance two connected historical arguments to help frame future study. First, from an ecological perspective, it becomes clear that Rome intervened in ongoing Italian practices of landscape management. It is perhaps no great surprise to learn that Iron Age societies were already shaping their practices to suit local climatic and environmental variability. However, the finer dynamics of Roman interaction with this background has yet to receive close study, and they tend to reveal a considerably nuanced situation. Roman expansion could intensify or otherwise change human-environmental relationships in direct but often indirect ways, and without always effacing local considerations. The second argument starts from the observation that Roman expansion occurred at the same time as consequential developments in Italy regarding the management of water and food supplies. Again, many of these practices were not initiated by Rome, but they saw the impact of expansion. These developments are read here as strategies of resilience, that is, as responses to environmental instability. That communities pursued risk-minimization in such visible ways forms a *prima facie* argument against the idea of a benign or historically irrelevant RWP. We trace how the evolving management of food and water made Italian communities robust to an unpredictable environment, and how Roman expansion impacted upon those efforts. Most pertinently, we argue that climate became most historically salient in relation to (or when mediated by) Italian society's resilience practices; through investments in capital or extensions of exchange networks, these practices produced sufficient resilience to deal with most variability attested in the scientific data but may have left communities especially vulnerable to more abrupt climate shocks that appeared in the Late Republic. We close by promoting this history of human responses to environmental variability during the period of Roman expansion in Italy as a topic for future study.

NATURAL ARCHIVES FOR CLIMATE

The literature for the scientific reconstruction of climate during the period of Roman expansion remains for the moment strongest on those global dynamics affecting Italy. The climate of Italy during the period of Roman expansion, as in all times and places, was the complex result of several subsystems operating at different spatial and temporal scales. This system comprised various components—atmosphere, ocean, land ice, vegetation cover, and so forth. During the first millennium BCE, the Central Mediterranean saw global and macroregional climate fluctuations related to changes in solar magnetic activity and North Atlantic Oscillation (NAO) variability. The NAO is a prominent and recurrent pattern of variability in atmospheric circulation over the North Atlantic. Its positive or negative mode reflects the strength of two hemispherical pressure patterns, a low near Iceland and high over the Azores and the subtropical region. In a negative mode, these features are weak, and storms tend to track directly across the western Mediterranean, bringing comparatively more precipitation to Italy and its surrounding region. The NAO thus represents a dominant source of atmospheric variability affecting the climate of the western and central Mediterranean on a multi-decadal scale. Reconstruction of the NAO index from a combination of lake cores, tree rings, and speleothems showed a mainly negative NAO phase interrupted by a brief positive phase around 750-500 BCE. Around 500 BCE, NAO shifted to negative and then returned to a prolonged positive phase about 150 years later.[7]

Negative phases of NAO correlated with minima in solar energy, placing importance on the climate forcing effects of variations in solar energy. Reconstruction of Total Solar Irradiance (TSI) showed two solar minima in the first millennium BCE. The first lasted from ca. 800-600 BCE, often referred to as the Halstatt or Homeric grand solar minimum. A second apparent minimum with almost identically low levels of TSI but lasting for shorter duration occured from around 375-250 BCE (fig. 1). From the later third century BCE, we see a period of comparatively high solar energy with spatially and temporally extensive resulting climate trends. The link between NAO and TSI suggests we understand periods of solar minima as relatively cooler and wetter in the West and Central Mediterranean.[8]

Figure 1. Global climate forcing trends affecting Italy in the first millennium BCE. Data sources: Faust et al., 2016 (NAO); Steinhilber et al., 2012 (TSI).

Recent work emphasizes explosive volcanism as the largest driver of short-term global climate variability. Sulfur dioxide gas, a major constituent in volcanic emissions, is transformed in the atmosphere to highly reflective sulfate aerosols that shield earth from solar radiation, resulting in cooler air temperatures. Sulfate aerosols are highly soluble so in smaller eruptions where the volcanic plume only extends into the troposphere, sulfate aerosols are removed by precipitation quickly, leading to relatively small, localized cooling. Ancient sources related eruptions of smaller volcanoes like Etna or Vesuvius during our period, but such activity was not significant enough to drive global effects. In larger eruptions when the volcanic plume reached the dry stratosphere, sulfate aerosols remaining in the atmosphere for months to years led to pronounced, longer term cooling at hemispheric to global scales.[9]

Volcanic sulfur fallout measured in polar and alpine ice cores provides detailed records of past explosive volcanism extending back thousands of years. The magnitude, seasonal timing, and location of the erupting volcano, in particular the latitude, largely determined the climate impacts. Recent technological improvements for ice core analyses have led to a rapid increase in the number of high-resolution volcanic fallout records for Roman antiquity. Linking climate drivers such as volcanic eruptions first to changes in precipitation and temperature and second to historical events requires exact and independent dating of all records, especially if inferring causality between them. Another important development has been improvement in ice chronologies based on annual layer counting of multiple seasonal chemical cycles preserved in the ice particularly during the past 2500 years.[10]

Records of volcanic sulfur measured in ice cores from Greenland and Antarctica suggested that explosive volcanism during the final three centuries BCE was somewhat low relative to the last 2500 years, at least until early 43 BCE. These records indicated that none of the 25 largest eruptions of the past 2500 years, and only three of the 40 largest eruptions, occurred between 300 and 44 BCE. Two larger eruptions fell in 430 and 426 BCE, and others clustered between 168 and 158 BCE. Climate effects of these latter, closely timed eruptions may have contributed to political instability in Ptolemaic Egypt.[11]

At the very end of our period, Arctic ice records indicated one of the largest eruptions of the past 2500 years in early 43 BCE followed by elevated atmospheric sulfate for nearly three years. Geochemical fingerprinting of volcanic tephra preserved in the ice show that the source was a massive eruption of the Okmok volcano in Alaska. Atmospheric modelling (Community Earth System Model, CESM, version 1.2.2) of the event suggested pronounced cooling in 43-2 BCE throughout the Northern Hemisphere, with annual average temperatures as much as 5°C cooler. These model results were consistent with global evidence from tree-rings and speleothems, which suggested 43 and 42 BCE were among the coldest of the last 2500 years. The CESM simulations indicated substantial climate effects in the area of Roman activity, including 4.5°C colder summer and fall average temperatures in 43 BCE, and 2°C colder winter and spring average temperatures in 42 BCE. Although precipitation is notoriously difficult to simulate, results suggested that 43 BCE summer precipitation was 50 to 120% above normal in southern Europe, with autumn precipitation up to 400% above normal in specific regions. Sources such as Josephus (*Ant.* 14.12.310) and Appian (*BC* 4.122, 5.25) reported extreme weather, famine, or epidemic disease from early 43 to late 42 BCE. It is possible that extreme climate shock resulting from the Okmok eruption disrupted food production, exacerbating sociopolitical unrest following the assassination of Caesar; we return to this possibility below.[12]

Information from global climate signals must be integrated with paleoenvironmental data at regional and local scales. As is typically the case, archives from areas closer to the historical events of Roman expansion offers data with a different, often lower, level of resolution and precision than global climate archives. The dossier of proxies available for local climate reconstructions in first millennium BCE Italy differs from that of other regions. In particular, we lack for Italy some of the highest quality sources of information found in neighboring areas of Europe or the Levant. While Alpine glacial ice from Colle

Gnifetti at the border between Italy and Switzerland offers geographically proximate information, published records only cover the last millennium CE. The absence for Italy of long tree ring chronologies extending through the Roman period is especially noteworthy, as it means that we cannot turn to the highly resolved dendrological indices of precipitation and temperature achieved for other parts of Europe. What there is in abundance for Italy is pollen, although for reasons discussed below, this material cannot be taken to reflect climate change except in a highly complex manner. [13]

In this situation, the most useful evidence for local Italian climate reconstruction during our period comes from study of oxygen isotope composition, usually expressed as δ-unit ‰, i.e. $\delta^{18}O$, in different terrestrial carbonate precipitates. These are especially represented by lacustrine marls and speleothems, cave calcite deposits like stalagmites and flowstones. The main advantage of the use of the $\delta^{18}O$ proxy is its supposed large insensitivity to human impact on environment as, in the Mediterranean region, $\delta^{18}O$ of lacustrine marls and speleothems are mainly considered controlled by local hydrology, with a more direct link to winter precipitation in speleothems and summer conditions for lacustrine sediments. There is also the advantage for speleothems of employing Uranium/Thorium dating which in some cases provides better chronology control than radiocarbon. Those elements have longer half-lives than carbon, making them preferable for earlier periods of the Holocene, while their calibration curves are also not susceptible to the problems of the Hallstatt plateau.[14]

Well-dated speleothem records from Italy covering the last 3000 years at decadal resolution remain limited to samples from a small handful of cave systems in north Central and North Italy. Figure 3 presents a selection of these speleothem records and one lacustrine succession from Lago di Pergusa in Sicily (for locations, see fig. 2). The chronological range of the selection starts with the late part of the so-called Homeric solar minimum of 800-600 BCE. At Pergusa this corresponds to a humid phase when wetter conditions also present at Rio Martino in northwest Italy. Wetter condition persist at Rio Martino between 600 and 400 BCE, when conditions become wetter also at Renella in the Apuan Alps. In the Northern Alps, a summer cooling phase is recorded between 380 and 300 BCE, corresponding to a cooling in sea surface temperature recorded in the Gulf of Lions. This phase sees drier conditions at Rio Martino and ushers in a long period of drier conditions at Renella. Apuan speleothem $\delta^{18}O$ records show a pattern of evident drier condition during the end of first century BCE. The drier period corresponds to lower summer temperatures in the Northern Alps. Interestingly, this dry-wet pattern is replicated in the Lago di Pergusa lower-resolution record, corroborating the finding in the northern part of the peninsula and, within age error, with the Rio Martino record. The wetter period may be linked with increased flooding events attested by historical accounts of Tiber floods, discussed below, and geoarcheological data from Northern Tuscany. The reconstruction of climate in the early centuries of the first millennium CE becomes elusive, either because of the different chronology of various records or the complexity of regional climate articulation and its imprinting in proxy data. In sum, for the latter half of the first millennium BCE, comparison of the speleothem $\delta^{18}O$ records shows some linked trends over decadal or centennial scales, but also variability in the more precise local timing or peaks of wetter or dryer phases. We also see regular oscillation between dryer and wetter conditions, suggesting regular climate variability within a certain range.[15]

Figure 2. Location of Italian and Central Mediterranean paleoenvironmental records discussed in text.

Figure 3. Selected $\delta^{18}O$ continental records from Italy. Data sources: see text.

In summary, available data for later first millennium BCE Italy confirmed a highly dynamic environment varying considerably across time and space, even as the period was comparatively free of short-term, abrupt climate changes. Global signals indicated a somewhat warmer period in the western and central Mediterranean regions commencing in the early third century BCE. The same period was relatively free of high-impact global volcanic activity, while the link between TSI and NAO suggested that this warmer period was also wetter in the Central Mediterranean area. Speleothems also showed increased wetness in Italy during the later first millennium BCE, but interestingly they indicated a somewhat later onset of humidity than that which appeared in the NAO data. The cumulative impression is therefore one in which climate global trends when viewed at local scales appeared diverse and must have remained unpredictable. In scientific terms, it seems impossible to speak of a single Italian or Roman climate in this period except at broad spatiotemporal scales not especially salient to historical interpretation.

POLLEN RECORDS

By far the most abundant form of local paleoenvironmental data for the period of Roman expansion in Italy are pollen records. This material merits special attention but reveals a complex relationship to discussion of climate change. The record of vegetation changes has substantially improved over the last few years with respect to the number and quality of records and their temporal resolution, but there remain aspects to bear in mind. Radiocarbon dating is the primary method applied to stratified pollen records. Earlier portions of our period fall within the so-called Hallstatt plateau, the time interval between 750 and 400 BCE when radiocarbon calibration returns dates with uncertainty intervals of several centuries. There is also the issue of extrapolation from pollen records to climate. There is significant debate within the scientific community about the interpretation of pollen records as signals of climate, with the main challenge being the differentiation of climatic from anthropogenic drivers of vegetation change. Special attention must be paid to pollen from the *Olea, Juglans,* and *Castanea* (OJC) group, known to reflect human cultivation. Recent work modeling large datasets suggests that Late Holocene pollen records in the main reflected demography, problematizing interpretations of the same data as signals of climate. At Lago di Pergusa in Central Sicily, a pilot study comparing isotopic data for precipitation with pollen records showed that enhanced humidity reflected different feedbacks in vegetation, suggesting anthropic drivers. The broader implication is that distinguishing Holocene climate changes based on pollen records alone is difficult if not impossible.[16]

Nonetheless, pollen records remain critical to any reconstruction of Italy's paleoenvironmental history both for their abundance and for their ability to speak to local human-environmental interactions.

Synthesizing a selection of available records revealed the long-term impact of human activity on vegetation during the whole of the Late Holocene (fig. 4-5; for locations, see fig. 2). OJC group pollen appeared in the Late Bronze Age in records from Lago Albano and Lago di Nemi in the Alban Hills, only a few kilometers from Rome. Bronze Age human impact on forest cover also appeared in records from Etruria and the Po plain. The Early Iron Age and Archaic period (1000 – 500 BCE) saw shifts in many Italian pollen records, although the impacts of human activity upon vegetation were by no means uniform or unilinear. Steady increase in tree cover started around 700 BCE in pollen recorded in a marine core from the Sicilian channel. In a record from Lago di Patria in Campania, the foundation of Greek colonies such as Cumae corresponded instead with temporary forest decline. In lake cores across Etruria at Lago dell'Accesa or Lago di Mezzano, we find forest clearance during the Iron Age but also shifts from deciduous oaks to olives and OJC pollen, reflecting Etruscan arboriculture and cultivation. Cereal cultivation appeared in Iron Age evidence from several regions, including Etruria, Latium, and outside from the Central Tyrrhenian region, for example in Messapian territory, where cereal pollen increased from 600 BCE onward in the record from Lago Alimini Piccolo north of Otranto.[17]

Figure 4. Summary chart of marine pollen records for first millennium BCE Italy discussed in text. Data sources: see text.

Figure 5. Summary chart of terrestrial pollen records for first millennium BCE Italy discussed in text. Data sources: see text.

This discussion confirms the expected point that Pre-Roman populations around the whole of Italy were intensifying use of local plant resources from an early date. Their efforts responded to factors such as settlement change, especially early urbanization, and demographic increase, trends discussed at greater length below. The overall pattern of progressive increase in human impacts on vegetation characterizes much of the Central Mediterranean. In western Sardinia, the pollen record of the Mistras lagoon showed a shift from grape and cereal culture to taxa typical of pasture around 300 BCE, before the Roman takeover of that island. Innovative practices were adapted to local environmental conditions. From Pompeii, a newly published sediment core from the Sarno bath complex just outside the city walls provides the first pollen sequence from the Sarno river floodplain from 900-750 BCE to the eruption of Vesuvius in 79 CE. Cabbage cultivation was introduced during the city's Samnite period (fourth to second centuries BCE). Planted during summer and harvested in late autumn and winter, this crop reflected a deliberate choice to suit naturally wet fields.[18]

Rome's entrance into a region sometimes corresponded to shifts in the vegetation history, although trends remained multilinear and revealed influences of local factors. At Pompeii, Roman colonists during the Sullan period intensified previous cabbage cultivation suited to local environmental conditions. Elsewhere, we sometimes see Roman activity represented by the intensification of ongoing practices. In a marine core from the Gulf of Gaeta in South Latium, forest development commenced around 500 BCE, while from 300 BCE showed signs of olive cultivation around the time of more focused Roman interest in the region. Often the magnitude of the impact on vegetation of Roman expansion during the Republican period was subtle, for example, a slight increase in chestnut pollen in Roman versus Pre-Roman samples from the Po plain. Many of these qualities come together to characterize the vegetation history of the Tiber River estuarine region around the site of Ostia, where several studies permit reconstruction of a wide marshland with well-developed sedge and reed swamps throughout much of the first millennium BCE. A slight increase in amaranth in the seventh century BCE may reflect early salt extraction. A core (PO1) taken south of the Tiber's paleochannel to the far west of the settlement contained an interval dated using AMS radiocarbon to 403-211 BCE, corresponding to the Mid-Republican establishment of the *castrum*. Human impact on vegetation was clearly attested in this phase, while deciduous oaks typical of coastal forests dominated the record. However, signals of human impact became clearest in the Imperial period following the creation of the artificial harbor at *Portus* in the first century CE. In this case as elsewhere, Roman impacts upon Italian vegetation during the Republican period often seem visible in pollen data as continuations or amplifications of ongoing trends, rather than abrupt or radical transformations.[19]

HISTORICAL ARCHIVES

Alongside data from natural archives, the reconstruction of the climate and environment of Italy during the period of Roman expansion offers the opportunity to consider information from historical records. Past Mediterranean societies are well known for relatively abundant written information. Such sources often capture details about environmental or climatic shifts, but in ways that reflect social or cultural attitudes. Thus, information from historical archives occupies a sort of middle ground between observations of past environmental trends and evidence for societal responses. For Italy, Theophrastus' *On Plants* detailed forests in Latium in the fourth-century BCE. Starting in the second century BCE, a tradition of Roman agronomic literature included works by Cato, Varro, and Columella. Further information was scattered through works like Pliny's *Natural Histories*. Of particular interest is phenological information in histories by authors like Cassius Dio or Livy, who sometimes opened or concluded discussions of annual events with notice of strange meteorological and natural phenomena. These histories were supplemented by more specialized works such as Julius Obsequens on prodigies, itself epitomizing Livy and other writers. An independent survey of information of this sort provided an annually resolved record of unusual natural phenomena that is relatively well-preserved from 509-293 BCE and 219-12 BCE. Within this range, some trends appeared: exceptional weather episodes and Tiber floods were more commonly reported in the second and first centuries BCE, perhaps reflecting increased wetness also seen in speleothems. Reports of famine and plague were distributed more evenly (fig. 6).[20]

Figure 6. Attestation of climate events in Roman Republican sources by decade, 509-27 BCE. Data sources: Cassius Dio, Livy, and Julius Obsequens.

This material's chronological structure is promising, although its integration into historical climate studies is not straightforward. A key challenge is the temporal distance between authors like Livy writing no earlier than the Late Republic and events occurring sometimes centuries earlier. Information on natural phenomena is assumed to have followed a complex path of transmission originating in now-lost priestly records. This transmission process has raised concerns about the record's reliability. While caution is not unwarranted, there are also reasons for optimism. First, it seems certain that Roman priestly archives contained meteorological phenomena. In the second century BCE, Cato differentiated his histories from priestly annals by stating that he did not care to write "how often grain was costly, or how often darkness or whatever obscured the light of the moon or sun" (*Origines* F80 Cornell). The implication is that priestly annals did record harvests and eclipses. Then, circumstantial support for early recording of natural phenomena comes from other Italian societies, particularly Etruria, where documents dating back to the fifth century BCE recorded meteorological information in the framework of the seasonal cycle and calendar. Finally, there are some possibilities for independent verification. Record of a solar eclipse in June of the 350th year after the foundation of Rome (Cic. *Rep*. 1.25) matched a known eclipse of 400 BCE. Severe outbreak of disease in the 420s BCE attributed to crop failure might be synchronized with a period of global cooling following explosive volcanic eruptions in 430 and 426 BCE, documented in Greenland ice cores, discussed above.[21]

While lending credence to historical archives, this discussion reinforces their sociocultural dimension. The function of priestly records as something other than straightforward accounts of natural phenomena meant that recording authorities focused only on unusual or exceptional events. Romans and Italians understood these as divine signs (*prodigia*) forming part of a communication system between humans and gods. As such, our information was also geographically limited to areas of Roman authority including Rome itself and Roman territory, with few exceptions. It was also deeply interwoven with religious and social qualities. Anomalous climate episodes were seen as prophetic indications of future events and prompted religious investigation and response, as in 363 BCE when natural disasters and disease prompted Romans to revive an old expiatory practice of hammering a sacred nail into the wall of the Temple of Jupiter Optimus Maximus (Livy 7.3). As scholarship on other periods stresses, religious responses to natural disaster could form important sources of social cohesion. What remains to be examined in our period is the extent to which climate shifts may have supported the development of new tools for recording natural phenomena. In other words, the practice of reading religious records of natural events could be flipped on its head, and the emergence of records themselves taken as signaling environmental shifts. Analogously, specific religious interventions might signal communal recognition of climate change and collective determination to mitigate them. In other premodern contexts, dramatic surges in temple building like that seen at Rome in the fourth to second centuries BCE have been linked to changes in precipitation. One temple built in the city in the mid-third century BCE was dedicated to the divine personification of bad weather, *Tempestas*.[22]

HUMAN RESPONSES

As these religious responses suggest, a reconstruction of Italian environment and climate in this period must incorporate historical and archaeological evidence to illustrate how Roman and Italian societies perceived of and managed environmental change. We turn now to consideration of these themes. The relationship between a landscape's natural parameters and its human exploitation is reciprocal. Land understood as marginal could encourage particular modes of exploitation. Climate variability or severe weather could destabilase food systems, but cultivation choices also affected how shifts in temperature or precipitation influenced productivity.[23]

What we are ultimately after in integrating scientific, archaeological, and historical evidence is an understanding of Italy's landscape as both physical and sociocultural entity. As this suggests, land and landscape were not neutral concepts, but richly cultural terms with equally strong social, economic, and political implications. Land was an entity to which people felt connected; land defined status, certainly in

Pre-Roman and Roman Republican Italy, through ownership, lease, tenancy, or landlessness. Land was also why territory was conquered and colonized. Land was inherently social, and local histories and people's identities were inextricably embedded in the landscape.[24]

The history of human interaction with landscape during the period of Roman expansion can be pursued along several lines. We have already seen the substantial potential of pollen records to throw light on the topic. Another increasingly vital approach is bioarchaeology. Bioarchaeological datasets capable of addressing issues of environmental or climatic change have not been a leading priority of research agendas until recently, but the situation steadily improves. Over the past two decades, sampling and study increasingly expanded from an initial, limited focus on easily recognizable carpological remains or wood artifacts to the analysis of data from a much greater variety of contexts, from wells to votive deposits, tombs, ships, or domestic and other spaces used for food preparation, consumption, or storage. This work reveals how new food items reached Italian consumers in the later Republic. In addition to native plants utilized for food like grapevine, olive, fig, walnut, hazelnut, chestnut, and dogwood, there were exotic species such as peach, date palm, melon, lemon, cedar, coriander, cumin, and sesame. As imports or often goods associated with restricted elite consumers, however, the consumption of these foodstuffs likely had little impact on agricultural choices or land use patterns.[25]

For our period, an important gain of recent research has been to demonstrate new ways of using established crop and livestock repertoires. Plant and animal remains from archaeological sites show that main species of staple crops and livestock exploited in the Republican period were essentially the same as in the Bronze Age: cattle, sheep and goats, pigs, hulled and naked wheats, barley, millet, emmer, fava beans, peas, and lentils. As far as staples were concerned, a diverse repertoire of plants continued to be cultivated, and no major change in crop-choice was associated with Roman expansion. There was a decrease in hulled wheat, but the unchanged representation of free-threshing wheat does not suggest it replaced other cereals, contrary to some previous suggestions. Diversity in crop types allowed for more than one annual harvest and guarded against seasonal variations in temperature or rainfall. Crop rotation and/or bare fallowing, suggested by several studies, helped maintain or improve soil productivity. Much about the particular practices of arable agriculture remains obscure, and future work might explore regional or temporal differences in approaches to similar crops.[26]

The zooarchaeological evidence for the period suggests several waves of change to the productive use of core species. First, increases in livestock body size were documented as early as the Bronze to Iron Age transition with continued increases over the first millennium BCE and into the Imperial period. Second, the relative importance of the main types of livestock shifted. In Central Italy and the southern Po plain, pig production expanded dramatically, while in the final centuries BCE, poultry farming was more widely adopted. Species abundance patterns resembling later imperial strategies appear to emerge in the second to first centuries BCE. Zooarchaeologists have repeatedly correlated these developments with changes of socioeconomic organization, particularly urbanization and demographic growth, greater connectivity, and increased focus on surplus production (fig. 7). Expansion in the production of pigs and poultry in particular points to interest in flexible, fast (maturing) food, which could be raised in a variety of environments throughout the year. In a landscape increasingly given over to cash-crops and arable staples, this reconfiguration of animal production formed a way of supplying meat to urban markets without competing for the best land.[27]

Figure 7. Relative abundance of pig and cattle remains expressed as percentage of number of identified specimens (NISP) from cattle, sheep/goat, and pig. Middle Bronze Age to 1st century BCE. Data source: Trentacoste and Lodwick (forthcoming).

Food production strategies were managed by human presence in the landscape, something survey archaeology increasingly makes visible. The Roman expansion marked a fundamental point of change in rural settlement patterns in Central Italy. To date, great attention has been paid to the emergence in Italy of villa sites presumed to have drawn upon newly available slave labor-forces. During the Republic, Italy's villa economy concentrated in particular regions such as the suburb around Rome or parts of Etruria. Villas often occupied well-watered and arable sites, and Roman agronomists advised owners to select favorable locations. Thus, their appearance rarely implied expansion onto marginal land but more often represented the enlargement of pre-existing settlement in response to changing markets. In terms of potential relationship to environmental change, more attention should be paid to the phenomenon of rural infilling. As noted in the introduction, we intend this phrase to refer to the rising density across Italy of smaller, not necessarily elite, sites. This proliferation of sites reflected intensifying land-use probably in combination with demographic increase, something demonstrated with respect to climate change in other periods. More data and testing is needed to determine the degree to which demographic growth drove rural site changes. Rather than new or more people, the primary thing a site's visibility to survey indicates is the use of a class of material at that site at that given time. A model contextualizing survey results within those wider networks distributing building materials or ceramics to rural locales would greatly nuance our understanding of how rural infilling reflected population growth in the countryside.[28]

Starting in the mid-twentieth century, the first systematic field surveys in Central Italy revealed a rise in and increased dispersion of rural ceramic scatters dated to the fifth to second centuries BCE. These trends were interpreted as the appearance of new, small farm sites linked with Roman territorial expansion, with Rome given primary agency in landscape change. However, synthesis and reanalysis of data from nineteen field surveys and ca. 2,500 sites from Latium and Etruria covering 700-200 BCE argued against direct causal links between ceramic scatters and Roman expansion, and instead promoted landscape transformation driven by fluctuations in exchange networks. These networks related to the distribution of materials visible to survey like tile or ceramics, and presumably also less archaeologically visible activities within the landscape like agriculture, ranching, or other productive activities affected by environmental shifts (Figure 8). Across Tyrrhenian central Italy, survey data pointed towards significant growth in rural activity between 500 and 200 BCE. Closer examination of each survey suggested that local and regional exchange networks, as well as patterns of material production and consumption across the social spectrum, played significant roles in turning sites "on" or "off" in the landscape and thus making them recoverable through survey. While the increase in sites takes place against a backdrop of aggregate demographic growth, survey results must be understood primarily as reflections of patterns in the production and consumption of durable material culture.[29]

Figure 8. Weighted average graph showing rural activity in central Italy from the 7th to 3rd centuries BCE. Data source: Samuels 2019. Sites were classified as elite or non-elite based on size and presence of luxury goods such as fine-wares and certain building materials.

Long-term continuity was apparent in substantial evidence for rural activity in most regions already by the seventh and sixth centuries BCE, when ceramic scatters were often closely associated with nucleated settlements or elite sites. Nucleation afforded control over production and consumption, especially for archaeologically visible materials like roof tiles and ceramics. Elites dominated exchange mechanisms in turn shaping the distribution of material culture and were themselves located in centralized (or more visible) locations. During this early period, non-elites were either invisible to field survey or tied to elite groups. The fifth and fourth centuries BCE saw fewer total sites across material classes and consumption types. This decrease in rural sites was associated with patterns of material change, as ceramics dated to this period were less diagnostic or missing entirely.[30]

The third century BCE saw significant material change, as rural activity that was mostly invisible in the fifth and fourth centuries BCE, and possibly also in the seventh and sixth, became visible. This trend was especially true at sites that were not clearly elite. Surveys suggest movement out from nucleated areas to areas closer to rural production such as fields, forests, or groves, with increased activity in areas identified as marginal land, a topic taken up below. Evidence suggested more intensive production or exploitation of new resources, while dispersed material culture suggested more permanent investment in activities across landscape types. These changes are often hard to correlate with the timing of Roman conquest, militating against interpretations of direct Roman interference. The trend of rural infilling in the later first millennium BCE was also not limited to Italy but appears across the Mediterranean, although the timing of rural settlement change becomes even more variable at wider geographical scales.

This picture of an Italian landscape in which Roman interventions encountered longer term dynamics coheres with trends in the pollen data discussed above. The idea may be further enriched by zooming in on particular areas of Roman expansion. As a focal region for early imperial expansion, Etruria offers good demonstration not only as a focal point for early Roman expansion in the fourth and third centuries BCE, but for its relatively well studied Pre-Roman society. Following Etruria's conquest, Romans reshaped the region's landscape by creating new colonies accompanied by port installations, canalization projects, roads, and reclaiming swampy areas for agricultural purposes. The intensive transformation of nutrient-poor soils into agrarian land in some cases allowed for fuller exploitation of conquered territory. At the same time, archaeological and paleonvironmental data expectedly show that Romans encountered a region of intensive prior human management. Early management was not limited to attempts to raise the marginal return on agricultural production to serve early regional urbanization and population growth from the Early Iron Age onward. Etruscan interests in fuel production for metallurgical activities related to abundant metal sources, for example, implied conscious preference for particular species with consequences for local forest cover.[31]

Roman expansion's insertion into systems of previous human activity in Etruria is encapsulated by the ship site of Pisa, San Rossore. This site, discovered in 1998, represents a remarkably well-preserved fluvial wharf where ships arrived to Pisa from the sea and from inland sites located along a network of canals. The wharf sat a few km from the ancient coastline along the Arno River, a major communication route linking interior to coast. Diachronic archaeological materials shows that human communities coexisted with the instability of this river catchment since the Neolithic. Data from the site and the Pisa plain suggest unstable environmental conditions with frequent floods of the Arno during the Roman Period. This trend is perhaps linked with the wet phase visible in speleothems discussed above. Repeated flooding only prompted a small shift of harbour activities northwards, but the general location of the port was largely maintained from the previous period. Rather than any extreme discontinuity of practice, the Roman period brought an intensification of previous efforts to maintain the site's location despite environmental adversity, in short, a story of increasing resilience.[32]

This Roman investment in resilience and infrastructure emphasized the interaction between social and biophysical forces, an interaction especially apparent in the exploitation of marginal land. In definitional terms, if one considers all profitable land in an area, that which is least profitable is deemed marginal. This land is potentially crucial for climate history because it is already on the cusp of viability and thus most likely to experience threshold changes based on minor contextual modifications. The addition of marginal land could be of great importance to the productive portfolio of individual households, while in Roman Republican society shifts could also have aggregate political impact by affecting the overall pool of landowners in a society. Roman citizens were classified according to whether they owned land and also according to that land's quantity and quality, so that voting privileges and tax burdens were affected by valuations of land's potential productivity. Decisions to cultivate marginal land could alter the state's tax base, increase registered landowners (*assidui*), or enfranchise landless Romans. Decisions about marginal land could therefore reconfigure the electoral balance or the pool of manpower available for conscription. Thus, to the extent that climate affected land profitability, it had sociopolitical effects in Republican Italy at levels of both household and state.[33]

Climate was one factor shaping decisions about whether and how to exploit land deemed marginal. Lo Cascio and Malanima suggest that one degree of warming raised the altitude threshold of wheat cultivation by 100-200 m in mountainous areas like Italy's Apennines due to longer growing seasons and rarer frosts, while aspects such as gradient, vegetation, erosion, water availability, and so forth, could affect this rule. Climate change could also alter productivity by drying wetlands or mitigating aridity, taking areas suitable for less profitable production and making them suitable for more profitable production. Alongside biophysical forces were human factors such as crop choices and selection, technology and capital investment, perishability and storage, access to markets, and so forth. The effects of biophysical factors often depended on the range of options available to households to diversify, store or redistribute. The historical impact of climatic change could thus be mitigated or intensified by the capacity of human action in response.[34]

The physical properties of land are extensively studied by soil scientists. While such science tends to focus on physical qualities, the gains of this research are applied to a wider and more socially defined perspective on land especially within the framework of applied anthropology and endeavors to introduce indigenous peoples across the globe to the advantages of modern soil science and agronomy. This effort began with the Land Evaluation Framework developed in 1976 by scientists working for the Food and Agriculture Organization (FAO) of the United Nations, who drew on a corpus of soil maps created to match land suitability with the technological capabilities of indigenous communities. Instead of simply introducing tractors to rural communities, as previously done, this was an attempt to fine-tune agriculture at the scale between land and society, based on assumptions that soil acts as intermediary and interface between people and land. This change of policy followed realization that local peoples could not only contribute labor but also what came to be called "indigenous knowledge."

In reconstructing past practices, historians and archaeologists can build on these insights. For example, GIS-based analyses would classify a simple flat plot as good arable land because of its lack of slope, but FAO's land evaluation's incorporation of indigenous knowledge suggests greater complexity. Roman and pre-Roman arable agriculture depended on animal traction and wooden plows, at best equipped with an iron shoe, which meant that soil could not be too heavy with a high clay fraction or too stony, as the plow would not be able to break the soil and would literally scratch the surface or bounce off stones. Stoniness and soil density were therefore key criteria in the FAO land evaluation. These locally known qualities can be elusive to broader, macrolevel evaluation. While agricultural tools like plows are reasonably well documented in Italy by archaeological finds for the first millennium BCE, ancient indigenous agricultural knowledge is harder to locate. However, sensitive archaeological inquiry can seek to reconstruct specific practices of past agrarian communities.[35]

One way to do this is by drawing from soil science applied to the excavation of paleosols, old land surfaces rapidly buried and then undisturbed. Micromorphological analysis reveals if buried soil has been plowed, while small charcoal fragments and a consistent distribution and grain size may suggest components were deliberately and consistently introduced. These are interpretable as evidence of burning off stubbles and other crop remains on the field that were then plowed into the soil to enrich phosphate content and increase yields. Another common way of fertilizing soil was with manure. Manuring may be detected through chemical analysis by measuring phosphate or by studying pottery fragments included in manure scattered over soil. An example of how the study of paleosols inform us about decisions regarding land-use and cultivation comes from the Terralba district directly adjacent to the Punic farm of Pauli Stincus. Situated on the south shore of the Gulf of Oristano in West Central Sardinia, the site is about 20 km from the Mistras lagoon on the Gulf's northern shores, whose pollen record described above revealed changing land-use practices ca. 300 BCE. The Sardinian site forms an excellent place for assessing the effects of imperial power on landscape, as its archaeology could relate the indigenous practices encountered by expanding Roman imperialism. At the site, an unusually large (20 x 10 m) buried plow soil was excavated in 2017. Archaeological, micromorphological and palaeobotanical analyses were used to study what was effectively an ancient agricultural field. The association with the Punic farmhouse and 34 diagnostic sherds found in the plow soil date it to the third-to-second century BCE. Results suggested the field, while not very large, was intensively worked and possibly irrigated for crops like vegetables or pulses.[36]

Study of the paleosol from Pauli Stincus emphasized the existing complexity of the rural economy of Punic Sardinia encountered by expanding Roman power. However fragmentary we see Italian society on the eve of Roman expansion, this emphasizes a connectedness of economy and society in ways that were sufficient to drive some level of adaptation and change. This complexity meant that the impact of environmental change was rarely straightforward or direct, just as historical and ethnographic studies reinforce the deep embeddedness of rural production in wider cultural, social, economic, and political structures. A hallmark of the complex agrarian world outlined here was intensification. The proliferation of dispersed rural settlement detectable through survey archaeology, as described above, evinced that same process across Italy, while a case study of a site like this offers a window onto how such intensification was achieved.[37]

HISTORIZICING RESILIENCE

The previous section emphasized how Rome encountered a world that was already actively building resilience through adaptation to landscape and environment. We have approached this topic at different scales, from peninsula-wide trends to the single farm site, and in Roman as well as Pre-Roman settings. While some degree of adaptation by Pre-Roman peoples to their ecological settings seems obvious, recently developed methodologies permit us to reconstruct these processes with considerable detail. The detailed study of Rome's intervention in this already complex world affords the possibility of historicizing an important case of the creation of societal resilience to environmental risk. In this section, we argue that resilience offers an excellent way to scale up from individual studies of localities to a broader environmental and climate history of the period. As applied to the making of Roman Italy, we intend resilience to describe the ability of Italian societies facing environmental unpredictability to maintain their structure or their trajectory of development. For our period, this last aspect is critical: resilience was not oppositional to change but the term also describes how dynamic societies continued along their paths of development. Two main ways societies created resilience are through capital investments and increasing connectedness – that is, by building robustness to variability or by extending networks across multiple ecologies. Such adaptations made societies more resilient, but they also introduced new elements with sometimes unexpected results. To illustrate this, we focus on how Italian communities and wider society managed two primary resources: water and food. In Mediterranean history, later first millennium BCE

Italy stands out for consequential developments in the technologies and practices of water management and food supply in response to natural variability.[38]

Many historical changes discussed in this paper's introduction connected closely to the ways in which Italians managed food and water supplies. Imperial integration impelled the circulation of new technologies, drove rising demand, created pools of capital for investment, and encouraged trade in agricultural products. Rising urbanization and population increase across Italy depended on new hydraulic technologies as well as upon the storage and delivery of foodstuffs to urban markets. At the same time, adaptations often formed part of a communities local and long-standing efforts to address typical Mediterranean climate variability. This aspect returns us to the interesting question, central to this study, of Rome's intervention in longer term human-environmental relationships. We suggest that evolving resilience strategies can shed light on the tension between locally specific practices and empire. Over the long run and especially by the Late Republic, we find that Italian food management strategies developed different and more robust features than those pertaining to the management of water. This divergence can be explained in part by focusing on the different resilience strategies available in both cases.

In Italy, the later first millennium BCE saw considerable innovations in hydraulic technology. These innovations largely sought resilience to water insecurity through capital investments. Rural infilling discussed above often accompanied the construction of new drainage systems. Some early projects seem imperial in nature. In the Pontine region, state investment relating to the construction of the via Appia in 312 BCE led to the elaboration of a system of canals to drain a marshy landscape and create arable land for incoming colonists. Rome's own aqueducts formed part of this history as impressive, innovative infrastructure requiring considerable resources to build and maintain. Ancient sources directly link Rome's first aqueducts to conquest, suggesting they were financed by war spoils.[39]

Empire thus could have an impact on how communities configured their relationship to local water resources. At the same time, many developments in the period of Roman expansion related to longer term and earlier processes of human adaptation. Rome's own early urban drainage system, the sixth-century

BCE "great sewer" (*cloaca maxima*), closely resembled the system of the Greek city of Cumae. Rome was one of many urban sites in Central and South Italy developing hydraulic infrastructure already by the Archaic period. Roman hydrological management of the Pontine landscape also finds precedent in largescale projects in the hinterlands of Kamarina or Metapontum by the fifth centuries BCE, where local hydrology or bradyseism caused fluctuations of water availability.[40]

This long-term trajectory should not come as a surprise, as communities across the peninsula worked constantly to manage local hydraulic resources. As discussed earlier with regard to other sets of evidence, Romans intervened in an already complex system. This balance featured in the inscription on a bronze tablet known as the *Sententia Minuciorum* (117 BCE), found in Serra Riccò in Liguria (*CIL* 1^2 584). The document related the Roman senate's legal settlement of a boundary dispute in the Polcevera Valley between the communities of the Viturii and Genuantes. The Latin text contained a lengthy catalog of local names for streams, water courses, and waterworks, knitting together imperial concerns with specific regional knowledge. Such close topographical awareness revealed iterative attempts of these communities to manage their water resources. The surrounding region of Liguria was an archetypal high-risk environment prone to erosion and flooding because of mountainous terrain and centuries of deforestation. Pollen data suggested landscape degradation during the second century BCE, compelling rural communities to mitigate risk of waterlogging, while impounding water for their own purposes. At Mogge di Ertola in the Aveto Valley, pollen records revealed decreased tree cover around 200-150 BCE. Around the same time, local inhabitants dammed and drained a water basin, sealing it with a layer of clay, and diverting nearby streams. Comparable small-scale manipulations of local water systems appeared in other valleys of the Ligurian Apennines. This activity's impulse stemmed from communities' desires to confront variable water ecologies, even as it took place around the time of Rome's Ligurian campaigns in the early second century BCE.[41]

The impact of Roman expansion on the resilience practices of Italian communities took many forms. Integration and markets could raise demand for water, intensifying local conflicts in situations of fragile hydraulic resources. Roman armies entering the Aosta valley in 140 BCE encountered an ongoing feud between the Salassi and the city of Vercellae. Our source, the Greek geographer Strabo described how the diversion of water from the Dora Baltea to the Salassi's gold washing operations negatively affected downstream irrigation; the situation led to violent conflict only settled by Roman intervention (4.7). Recent research reveals how, between 200 BCE and 150 CE, the Dorea Baltea basin was characterized by heavy floods and rains, probably linked to glacial retreat near the river's Alpine sources, perhaps related to climate trends described above. These factors in tandem with heightened sedimentation pushed the confluence between the Dora Baltea and the Po rivers 10 km westward, creating a series of new riverbeds and terraces. This landscape change more likely lay behind hydrological variability than the probably limited impact of water impounded for gold washing. However, rising demand for precious metal exacerbated an already precarious situation, driving conflict.[42]

The most obvious way that imperialism affected adaptations was through capital investment. In some cases, the Roman state directly invested in Italian hydraulic infrastructure, although always with good awareness of the parameters and capabilities of a site's hydraulic resources. Consider the Latin colony of Cosa founded in 273 BCE on a hilly outcrop along the Etruscan coast. Cosa's location provided military advantages but lacked natural water sources, offering only modest annual rainfall (460-560mm). The problem of water merited attention from the colony's foundation, with the construction of numerous paved and slightly canted surfaces, as well as conduits, directing seasonal runoff into several large reservoirs. Cosa's story was not one of investment in adaptation leading to unstinted success, but rather shows the difficulty overcoming fragile hydraulic resources even with state-level investment. The colony initially struggled to maintain its population, requiring a supplement of colonists in the early second century BCE. Over the long run, however, Cosa's system not only sustained basic needs but supported a thermal bath complex by the early Empire.[43]

Large cisterns at other colonial sites reveal a similar pattern of state investment combined with the more continuous or longer term need to build resilience in the face of seasonal and episodic periods of water glut or shortage. At Segni, ancient Signia in Latium, a Roman colony of the sixth century resettled in 495 BCE, excavations revealed a monumental cistern of the later second century BCE replacing a previous system of smaller cisterns. Across the peninsula in Apulia, the remarkable network of basins and conduits known as the *vasche limarie* of the old Messapian settlement of Brundisium, the site of a Roman colony around 244 BCE, showed three phases of expanding configuration, from a modest system of wells and pipelines of the third century BCE to a fully-fledged distribution network by the second century CE. In these cases, the creation of monumental cisterns around the time of colonial foundation represented important moments in the history of each site's struggle against water fragility, but the elaboration of urban water supply was always more temporally expansive. Within Republican Italy, investments to local systems of water supply could provide for urban expansion, but the system as a whole never became resilient to the point of alleviating concerns over water supply or the need for continuous efforts.[44]

We may compare this pattern of resilience to that seen with the development of Italian systems of food storage and distribution. Grain, wine, and olive oil, the three main components of the Mediterranean diet, were readily storable and exchangeable commodities but were nonetheless susceptible to processes of deterioration. Containers and warehouses protected foodstuffs against bad harvests or pests, and against historical forces like warfare or shifting labor supplies or property-ownership. The last centuries of the first millennium BCE were formative for Italy's food system. Practices again formed part of longer-term trends relating to a background of environmental instability. The use of large ceramic containers for household storage went back well into the prehistoric period. Survey of multipurpose storage jars called *pithoi* shows how food storage was closely entangled with arable agriculture and urbanism from eighth to fifth centuries BCE. Thanks to their insulating properties, *pithoi* expanded carrying capacity by conserving wine, olive oil, grain, and other foods at rural and urban sites. Storerooms, in some cases purpose-built to host one or more *pithoi*, were constructed at various sites during the Iron Age.[45]

Storage facilities and implements became more archaeologically visible and specialized over the final three centuries BCE. Focusing on a synthesis of the literature for Central Italy, we find that distinct storerooms appeared in rural estates mostly from the second century BCE onwards. The earliest granaries, built separate from or on the edge of villas, featured central rows of piers or pillars to divide rooms internally or support upper storeys. In the second century BCE, at least seven large storerooms were constructed. In the following century, almost twice that number were constructed. In the first century CE, thirty-nine storerooms are attested, continuing the upward trend. These were somewhat smaller storerooms, perhaps reflecting a strategy to disperse stored grain across different spaces to mitigate risk. Overall, storage facilities increased, as the total of storerooms in operation during the first century CE is almost sixfold more than those in the second century BCE and more than double the first century BCE (fig. 9).[46]

Figure 9. Granaries and *cellae* built and in operation in Italy, ca. 200 BCE – 100 CE. Data sources: Marzano 2007; van Oyen, 2015; *eadem*, 2020; Pellegrino 2017.

Bulk liquid storage of wine and oil became more specialized at rural sites over the same period. From the third century BCE onwards the use of *dolia*, large ceramic jars specifically designed for wine production, grew drastically at elite rural sites in central Italy. *Dolia* appeared across central Italy in significant numbers starting in the second century BCE. Their placement spoke to increased specialization of farming processes, with storerooms with *dolia* (*cellae*) often connected to pressing rooms. The number of *cellae* in operation doubled from second to first centuries BCE and almost doubled again in the following century. The number of *dolia* in use increased over sevenfold from second to first centuries BCE, from 14 to 103.[47]

Food storage was critical in urban areas, too, where increasingly specialized infrastructures and technologies appeared over the later first millennium BCE. In major cities like Ostia and Rome, by the late Republic at the latest storehouses for grain and other goods featured multiple rooms with thick, insulating walls, raised floors, and small windows for ventilation.[48]

By the last two centuries BCE, converging trends facilitated a robust Italian food supply operating on unprecedented scales. At the same time, Roman agronomic treatises were stabilizing productive knowledge, the reorganized Roman calendar facilitated interregional coordination, and new ports and roads lowered transaction costs. Increased resilience drove expectations, creating a feedback loop. Starting in the later second century BCE, Rome's urban *plebs* received monthly grain subsidies supplied by the state. The capital housed a massive population, and the demands of this *annona* system prompted further investments in storage and trade. By the Late Republic, the system formed a potent source of political power, as leaders like Clodius, Pompey, or Caesar manipulated public food subsidies in search of popular political support. Rome's *annona* found reflection in Italian towns where elites sought power and status by intervening in local food supply. In a recently published inscription from Pompeii, a local grandee boasted of sustaining the city's population with subsidized bread distributions during a four-year famine.[49]

As described here, food and water management practices in Italy during Roman expansion responded to a similar background but ultimately followed different trajectories. Resilience in systems of water supply was generally a matter of capital investment rather than connectedness. Water resources were always highly local, obedient to available water courses, springs, or aquifers. Close knowledge of local resources remained vital even in situations of state intervention. Aqueducts or canals could extend natural channels over distance, but never to the extent of food supply, which was considerably more scalable by means of long-distance trade. As this suggests, resilience in the food supply could be created by connecting markets in ways that were simply unavailable in the case of water supply. When the food trade combined with impressive storage infrastructure, as happened at Rome and Italy by the Late Republic, it produced a food supply system with high capital, connectivity, and resilience. Resilience theory notes how this combination holds potential for the emergence of rigidity traps in which strong feedbacks worked to maintain the status quo. This, we argue, was precisely what happened in Late Republican Rome, when an enhanced food supply and concomitantly heightened expectations became closely interwoven into Roman politics. Identification of this rigidity trap lends support to the idea of political fallout from volcano-forced climate change affecting agricultural production, as hypothesized in the aftermath of the eruption of Okmok in 43 BCE, discussed above. At the same time, relating the impact of abrupt climate change to a rigidity trap, which emerged after centuries of development as local practices were scaled up under imperial pressures, reinforces the need to attend to longer run dynamics.[50]

CONCLUSIONS

This discussion leads back to introductory remarks about more punctuated or diachronic versions of historical climate studies. In the end, interactions between longer- and shorter-term trends revealed this to be a false choice: the environmental and climate history of Italy during the period of early Roman expansion was a meshwork of complex processes operating at different but interrelated scales. We suggested a guiding question for the historical climate studies of this period concerned the role of environment and climate in the making of Roman Italy. The sum of our discussion is to encourage historians to avoid the overly simplifying idea of a predictably stable or benign RWP causative to Roman expansion. Global climate patterns trended towards slightly warmer and possibly wetter conditions over Italy from around 300 BCE. However, available scientific data suggested that the local expression of this environmental and climate change was often variable and had sometimes contradictory effects.

The human side of this history also presented issues of scalar integration, moderating between the integrative and globalizing force of the Republican state and the variability and contingency of local land-use practices. Clearly, Rome intervened in Italian societies that were already developing land-use practices to suit local parameters. However, it is not sufficient to conclude that environmental history in this period was entirely local, as we have observed both the connectedness of Pre-Roman practice as well as the impacts of Roman expansion. For those working in the disciplines brought together here, there remains considerable room to explore the interaction of different concerns in greater detail from a variety of angles. We sketch out some of the historical dynamics as this paper has described them. Throughout, a recurrent theme has been intensifications of landscape-use achieved despite, or often because of, environmental and climate variability. Far from being a period of passive disinterest in climate or general climatic favourability, the last centuries of the first millennium BCE were marked by critical developments in Italian communities' adaptations to variability, as histories of water and food supply management have especially revealed. Generally, increasing returns on land—through selection of animals, extensifying rural settlement, modifying farming practices, or investing in water capture and food storage—bettered a community's chances in an environment that was always to some degree stochastic. The drivers behind these changes were often initially local, as adaptations were always oriented towards specific parameters of place and landscape and local, indigenous knowledge of such. Consequently, in each community or even every farmstead, adaptive responses remained diverse and multilinear. Roman imperialism intervened in this already complex world, as expansion could and did affect local behavior. Rome's impact on landscape could be as straightforward as the establishment of a colony or building infrastructure to support the grain trade. More often than not, however, its impact was indirect. This much was suggested by chronological mismatches between the arrival of Roman power into particular regions and, among other trends, the timing of changes in agricultural and animal husbandry practices detectable by bioarchaeology, of rural infilling detectable by survey, or of vegetation histories visible in pollen data. Imperialism especially encouraged market practices, which intensified longer running local trends. By the first century BCE, the integration of Italy advanced to a point where the level of connectedness started to look different. Numerous local responses by their aggregate had begun to scale up to a peninsula-wide food supply system. This increased expectations, making a system robust to environmental variability within a certain range susceptible to disturbances of exceptional magnitude, as may have happened at the end of the Republic.

An emphasis on the interplay of Roman expansion with local practices or community-based agency tends to push back against centrist or statist reconstructions focused primarily on Rome, even as we have noted Roman imperialism's fundamentally territorial dimensions in Italy. Of course, we by no means intend to exclude Roman power as a driver of change in human relationships with the environment in this period, but rather to emphasize the need to account for the interplay of multiple factors. Indeed, one tangible benefit of evidence brought forward by this paper is that much of it is explicitly *not* Roman. As the study of Roman expansion in Italy increasingly considers indigenous or non-state perspectives, environmental datasets offer considerable potential to reveal histories of places and peoples without the filter of imperial ideology. We should work to incorporate this material not as singular, isolated cases of local practice, but as part of a more complex and dynamic system. In this way, as our picture of the environmental and climate history of the Roman expansion in Italy becomes more detailed, it holds the potential to become more balanced. We close with the hope that this paper serves as invitation to further study and collection of scientific, archaeological, and historical data from this critical period.

[1] The phrase "historical climate studies" from Dagomar Degroot, et al. "Towards a rigorous understanding of societal responses to climate change," *Nature* DXCI (2021), 539-50; see also Sverker Sörlin and Melissa Lane, "Historicizing climate change—engaging new approaches to climate and history," *Climatic Change* CLI (2018), 1-13. From the considerable literature on the Anthropocene and historical climate studies, see Deepak Chakrabarty, "The Climate of History: Four Theses," *Critical Inquiry* XXXV (2008), 197-222; Adam Izdebski et al. "Realising consilience: how better communication between archaeologists, historians and geoscientists can transform the study of past climate change in the Mediterranean," *Quaternary Science Reviews* CXXXVI (2016), 5-22; Catherine Kearns, "Mediterranean archaeology and environmental histories in the spotlight of the Anthropocene," *History Compass* (2017); John Moreland, "AD 536 – Back to nature?" *Acta Archeologica* LXXXIX (2018), 91-111; for work on Roman antiquity showing focus on later periods, Michael McCormick et al. "Climate Change during and

after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence," *Journal of Interdisciplinary History* 43.2 (2012), 169-220; Kyle Harper, *The Fate of Rome: Climate, Disease and the End of an Empire*, (Princeton, 2017); Kyle Harper and Michael McCormick, "Reconstructing the Roman Climate," in Walter Scheidel, ed. *The Science of Roman History: Biology, Climate, and the Future of the Roman Past*, (Princeton, 2019), 11-52; Adam Izdebski and Michael Mulryan, eds. *Environment and Society in the Long Late Antiquity* (Leiden, 2019). See now Paul Erdkamp, Joseph Manning, and Koenraad Verboven, eds. *Climate Change and Ancient Societies in Europe and the Near East: Diversity in Collapse and Resilience* (New York, 2021).

[2] Reliable introduction to the historical narrative appears in Alan Astin et al., eds. *The Cambridge Ancient History, Vol. VIII. Rome and the Mediterranean to 133 BC*, 2nd edition (Cambridge, 1990). Among more recent works, see Nicola Terrenato *The Early Roman Expansion into Italy: Elite Negotation and Family Agendas* (Cambridge, 2019); Marian Helm, *Kampf um Mittelitalien Roms ungerader Weg zur Großmacht* (Stuttgart 2021). For Pre-Roman Italy, see Stéphane Bourdin, *Les peoples de l'Italie préromaine* (Paris, 2012); for archaeological evidence relating to territory, see Elio Lo Cascio and Alfredina Storchi Marino, eds. *Modalità insediative e strutture agrarie nell'Italia meridionale in età romana* (Bari, 2001). For imperialism in North Italy, see Elio Lo Cascio and Marco Maiuro, eds. *Popolazione e risorse nell'Italia del nord dalla romanizzazione ai Longobardi* (Bari, 2017). On colonization, Tesse Stek and Jeremia Pelgrom, eds. *Roman Republican Colonization: New Perspectives from Archaeology and Ancient History* (Leiden, 2014). On Roman organizations of landholding, see Saskia Roselaar, *Public Land in the Roman Republic: A Social and Economic History of* Ager Publicus *in Italy, 396-89 BC*, (Oxford, 2011).

[3] On urbanization, Jamie Sewell, "Higher-Order Settlements in Early Hellenistic Italy: A Quantitative Analysis of a New Archaeological Database," *American Journal of Archaeology* CXX (2016), 603-30. On demography, Luuk de Ligt, *Peasants, Citizens and Soldiers: Studies in the Demographic History of Roman Italy 225 BC – AD 100* (Cambridge, 2012); Saskia Hin, *The Demography of Roman Italy*

(Cambridge, 2013). On economic changes including monetization, Nathan Rosenstein, *Rome at War: Farms, Families, and Death in the Roman Republic* (Chapel Hill, 2004); James Tan, *Power and Public Finance at Rome, 264-49 BC* (Oxford, 2017); Tymon de Haas and Gijs Tol, eds. *The Economic Integration of Roman Italy. Rural Communities in a Globalizing World*, (Leiden, 2017); Saskia Roselaar, *Italy's Economic Revolution: Integration and Economy in Republican Italy* (Oxford, 2019).

[4] Earlier debate on Roman imperialism can be accessed through Craige Champion, *Roman imperialism: readings and sources* (Oxford, 2004); scholarship since includes Arthur Eckstein, *Mediterranean Anarchy, Interstate War, and the Rise of Rome*, (Berkeley, 2006); Terrenato 2019; Dan-el Padilla Peralta, "Epistemicide: The Roman Case," *Classica* XXXIII (2020), 151-86.

[5] John-Bryan Ward-Perkins, "Etruscan Towns, Roman Roads and Medieval Villages: The Historical Geography of Southern Etruria," *The Geographical Journal* CXXVIII (1962), 389-404; for newer data from the vicinity, see below.

[6] For a collection of dates suggested for the RWP's onset, see Harper 2017: 321 n. 46; the idea goes back at least to Hubert Lamb, *Climate, History and the Modern World*. Second Edition (London, 1995), 142; see also McCormick et al. 2012: 203; Harper and McCormick 2018; James Tan, "Climate Change and Rome's Changing Republic," in Mattia Balbo and Federico Santangelo, eds. *A Community in Transition: Roman History, 200-134 BC* (Oxford, forthcoming); Giulia Margaritelli, et al. "Persistent warm Mediterranean surface waters during the Roman period," *Scientific Reports* X (2020).

For initial scientific critique of the RWP in Italy, see Monica Bini et al., "Hydrological changes during the Roman Climatic Optimum in northern Tuscany (Central Italy) as evidenced by speleothem records and archaeological data," *Journal of Quaternary Science* (2020).

At Mediterranean scales, a growing literature points to hydrological variability during the Roman period: 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* (2018) XVI; Elena Xoplaki et al., "Hydrological Changes in Late Antiquity: Spatio-Temporal Characteristics and Socio-Economic Impacts in the Eastern Mediterranean," in Erdkamp, Manning, Verboven, eds. (2021): 533-60.

[7] For introduction, see Eduardo Zorita et al. "The Global Climate System," in Sam White, Christian Pfister, Franz Mauelshagen, eds. *The Palgrave Handbook of Climate History*, (New York, 2018), 21-26. For NAO, see James W. Hurrell et al., *An Overview of the North Atlantic Oscillation*, Geophysical Monograph Series (2003); Harper and McCormick 2018: 15; Celia Martin-Puertas et al., "Regional atmospheric circulation shifts induced by a grand solar minimum" *Nature Geoscience* V (2012), 397-401. Leslie J. Gray et al., "Solar influences on climate," *Reviews of Geophysics*, XLVIII (2010), RG4001. Jesper Olsen et al., "Variability of the North Atlantic Oscillation over the past 5,200 years," *Nature Geoscience*, V (2012), 808-812. Ilya Usoskin et al., "Grand Minima and Maxima of Solar Activity: New Observational Constraints," *Astronomy & Astrophysics,* CDLXXI (2007), 301–309. Gerard Bond et al., "Persistent solar influence on North Atlantic climate during the Holocene," *Science* CCXCIV (2001), 2130-2136; Johan C. Faust et al., "Norwegian Fjord Sediments Reveal NAO Related Winter Temperature and Precipitation Changes of the Past 2800 Years," *Earth and Planetary Science Letters,* CDXXXV (2016), 84–93.

[8] Bond et al. 2001; Friedrich Steinhilber et al. "Total solar irradiance during the Holocene," *Geophysical Research Letters*, XXXVI (2009); Luis E.A. Vieira et al., "Evolution of solar irradiance during the Holocene," *Astronomy & Astrophysics* DXXXI (2011).

[9] Michael Sigl et al. "Timing and climate forcing of volcanic eruptions for the past 2,500 years," *Nature* DXXIII (2015), 543-549; cf. Gill Plunkett et al. "No evidence for tephra in Greenland from the historic eruption of Vesuvius in 79 CE: Implications for geochronology and paleoclimatology," *Climate of the Past*, XVIII (2022), 45-65.

[10] Jihong Cole-Dai et al. "Comprehensive Record of Volcanic Eruptions in the Holocene (11,000 years) From the WAIS Divide, Antarctica Ice Core," *Journal of Geophysical Research: Atmospheres,* CXXVI (2021); Sigl et al. (2015); Anders Svensson et al. "Bipolar volcanic synchronization of abrupt climate

change in Greenland and Antarctic ice cores during the last glacial period', *Climate of the Past,* XVI (2020), 1565-1580; Joseph R. McConnell et al. "Pervasive Arctic lead pollution suggests substantial growth in medieval silver production modulated by plague, climate, and conflict," *Proceedings of the National Academy of Sciences of the United States of America,* CXVI (2018), 14910-14915; uncertainties in the most up-to-date ice chronologies are probably <1 year for antiquity.

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[12] Joseph R. McConnell et al. "Extreme climate after massive eruption of Alaska's Okmok volcano in 43 BC and its effects on the civil wars of the late Roman Republic," *Proceedings of the National Academy of Sciences of the United States of America* (2020); for CESM, see James Hurrell et al. "The Community Earth System Model: A Framework for Collaborative Research," *Bulletin of the American Meteorological Society,* XCIV (2013), 1339-1360; for sources, P.Y. Forsyth, "In the wake of Etna, 44 B.C.," *Classical Antiquity,* VII (1988), 49-57.

[13] We thank Mauro Bernabei for discussing Italian dendrology; for glacial records, see Enrico Mattea et al. "Firn changes at Colle Gnifetti revealed with a high-resolution process-based physical model approach," *The Cryosphere* XV (2021), 3181–3205.

[14] Giovanni Zanchetta et al. "Enhanced rainfall in the western Mediterranean during deposition of Sapropel S1: stalagmite evidence from Corchia Cave (Central Italy)," *Quaternary Science Reviews*, XXVI (2007), 279-286; C. Neil Roberts et al. "Stable isotope records of Late Quaternary climate and hydrology from Mediterranean lakes: the ISOMED synthesis," *Quaternary Science Review* XXVII (2008), 2426-2441; Michael D. Jones, C. Neil Roberts, Giovanni Zanchetta, "Oxygen isotopes as tracers of Mediterranean variability: linking past, present and future," *Global and Planetary Change* LXXI (2010); Monica Bini et al. "The 4.2 ka BP Event in the Mediterranean Region: an overview," *Climate of the past*, XV (2019), 555–577.

[15] There are essentially three published speleothem records from peninsular Italy for our period: Corchia, Renella, and Rio Martino. Outside our area but for the Central Mediterranean, note a newly published Roman-era record from the Bàsura cave in Toirano published by Hsun-Ming Hu et al., "Stalagmite-Inferred Climate in the Western Mediterranean during the Roman Warm Period," *Climate* X (2022) and a multi-sample study from Mallorca, Mercè Cisneros et al., "Hydroclimate variability during the last 2700 years based on stalagmite multi-proxy records in the central-western Mediterranean" *Quaternary Science Review* CCLXIX (2021). As background for climate interpretation, figure 2 reports summer temperature reconstruction obtained by trees for the North Alpine region after U. Büntgen et al., "2500 Years of European Climate Variability and Human Susceptibility," *Science* CCCXXXI (2011), and temperature from marine records obtained in the Gulf of Lions after Bassem Jalali et al. "Holocene climate variability in the North-Western Mediterranean Sea (Gulf of Lions)," XII (2016), 91-101; for speleothem data, see Bini et al. 2020; Eleonora Regattieri et al., "Holocene Critical Zone dynamics in an Alpine catchment inferred from a speleothem multiproxy record: disentangling climate and human influences," *Scientific Reports*, IX (2019), 17829; Giovanni Zanchetta et al., "Insight into summer drought in southern Italy: palaeohydrological evolution of Lake Pergusa (Sicily) in the last 6700 years," *Journal of Quaternary Science*, in press.

[16] For OJC, see Anna Maria Mercuri et al. "Olea, Juglans and Castanea: the OJC group as pollen evidence of the development of human-induced environments in the Italian peninsula," *Quaternary International* CCCIII (2013), 24-42. For Lago di Pergusa, Laura Sadori and Biancamaria Narcisi, "The postglacial record of environmental history from Lago di Pergusa (Sicily)," *The Holocene*, XI (2001), 655-671; Laura Sadori et al. 2013. "The last 7 millennia of vegetation and climate changes at Lago di Pergusa (central Sicily, Italy)," Climate of the Past 9: 1969-1984; 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* CXXXVI (2016), 173-188. For recent discussions of pollen and anthropogenic or climatic drivers, see Ralph M. Fyfe et al., "Trajectories

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[17] Anna Maria Mercuri et al., "A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po valley as a result of human impact and climate change", *Vegetation History and Archaeobotany* XXI (2012), 353–372; Carla A. Accorsi et al. "Holocene forest vegetation (pollen) of the Emilia-Romagna plain, Northeastern Italy," in Franco Pedrotti, ed. *La vegetation postglaciaire du passé et du présent syngenése* (Berlin, 2004) 110–140; Fabrizio Michelangeli et al., "Three Millennia of Vegetation, Land-Use, and Climate Change in SE Sicily," *Forests*, XIII (2022), 102; Anna Maria Mercuri et al., "The long history of Cannabis and its cultivation by the Romans in central Italy, shown by pollen records from Lago Albano and Lago di Nemi", *Vegetation History and Archaeobotany*, XI (2002), 263-27; Federico Di Rita et al., "Late Holocene environmental dynamics, vegetation history, human impact, and climate change in the ancient Literna Palus (Lago Patria; Campania, Italy)," *Review of Palaeobotany and Palynology*, CCLVIII (2018), 48–61; Michel Magny et al., "Holocene climate changes in the central Mediterranean as recorded by lake-level fluctuations at Lake Accesa (Tuscany, Italy)," Quaternary Science Reviews, XXVI (2007), 1736-1758; Rith Drescher-Schneider et al., "Vegetation history, climate and human impact over the last 15,000 years at Lago dell'Accesa (Tuscany, central Italy)," *Vegetation History and Archaeobotany* XVI (2007), 279-299; Marta Mariotti Lippi et al., "The Massaciuccoli Holocene pollen sequence and the vegetation history of the coastal plains by the Mar Ligure (Tuscany and Liguria, Italy),"

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[18] Federico Di Rita and Rita Teresa Melis, "The cultural landscape near the ancient city of Tharros (central West Sardinia): vegetation changes and human impact," *Journal of Archaeological Science* XL (2013), 4271–4282; Cristiano Vignola et al., "At the origins of Pompeii: the plant landscape of the Sarno River floodplain from the first millennium BC to the AD 79 eruption," *Vegetation History and Archaeobotany* 31(2), 171-186.

[19] Federico Di Rita, et al., "Late Holocene forest dynamics in the Gulf of Gaeta (central Mediterranean) in relation to NAO variability and human impact," *Quaternary Science Reviews*, CLXXIX (2018), 137–152. Federico Di Rita, et al., "Holocene forest dynamics in central and western Mediterranean: periodicity, spatiotemporal patterns and climate influence," *Scientific Reports*, VIII (2018), 8929. Federico Di Rita, et al., "Climate and Human Influence on the Vegetation of Tyrrhenian Italy during the Last 2000 Years: New Insights from Microcharcoal and Non-Pollen Palynomorphs," *Geografia Fisica e Dinamica Quaternaria*, XLII (2019), 203–214; for complete study of the Gulf of Gaeta core C5 see: Giulia Margaritelli et al., "Marine response to climate changes during the last five millennia in the central Mediterranean Sea," *Global and Planetary Change*, CXLII (2016), 53-72. For Ostia, see Federico Di Rita et al., "Holocene environmental instability in the wetland north of the Tiber delta (Rome, Italy): sea-lake-man interactions," Journal of Paleolimnology, XLIV (2010), 51–67; Piero Bellotti et al., "The Tiber river delta plain (central Italy): coastal evolution and implications for the ancient Ostia Roman settlement," *The Holocene*, XXI (2011), 1105–1116; Jean-Philippe Goiran et al. "Geoarchaeology confirms location of the ancient harbor basin of Ostia (Italy)," *Journal of Archaeological Science* XLI (2014), 389-398; Laura Sadori et al. "Palynology and ostracodology at the

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[23] Alain Bresson, "Fates of Rome," *Journal of Roman Studies* CX (2020), 233-46, p. 236; Frits Heinrich and Annette Hansen, "A Hard Row to Hoe. Ancient Climate Change from the Crop Perspective," in Erdkamp, Manning, Verboven, eds. (2021), 25-80.

[24] A large anthropological literature on this point includes Keith Basso, *Wisdom Sits in Places: Landscape and Language Among the Western Apache*. (Albuquerque, 1996); Peter Geschiere, *Perils of Belonging. Autochthony, Citizenship, and Exclusion in Africa and Europe* (Chicago: 2009).

[25] On the field in general, see Lisa Lodwick and Erica Rowan, "Archeobotanical Research in Classical Archaeology," *American Journal of Archaeology* MXXVI (2022), 593-623. Otherwise, Emilia Allevato et al., "Pollen-wood analysis at the Neapolis harbour site (1st–3rd century AD, southern Italy) and its archaeobotanical implications," *Journal of Archaeological Science*, XXXVII (2018), 2365–2375; Marta Mariotti Lippi et al., "The Botanical Record of Archaeobotany Italian Network - BRAIN: A cooperative network, database and website," *Flora Mediterranea* XXVIII (2018), 365–374; Clemènce Pagnoux, et al., "The introduction of *Citrus* to Italy, with reference to the identification problems of seed remains," *Vegetation History and Archaeobotany*, XXII (2013), 421-438; Laura Sadori et al. The introduction and diffusion of peach in ancient Italy," in Jean-Paul Morel and Anna Maria Mercuri (eds.), *Plants and Culture: Seeds of the Cultural Heritage of Europe*, (Bari, 2019), 45–61.

[26] For synthesis of bioarchaeological material, see Angela Trentacoste and Lisa Lodwick, "Republican agriculture and animal husbandry in context: towards an agroecology of the Roman expansion," in Seth Bernard, Lisa Mignone and Dan-el Padilla Peralta (eds.), *Making the Middle Republic: New Approaches to Rome and Italy, 400-200 BCE*, Cambridge (forthcoming); otherwise, Laura Motta and Katherine Beydler, "Agriculture in Iron Age and Archaic Italy" in David Hollander and Timothy Howe (eds.), *A*

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[27] Angela Trentacoste, et al. "New trajectories or accelerating change? Zooarchaeological evidence for Roman transformation of animal husbandry in Northern Italy," *Archaeological and Anthropological Sciences*, XIII (2021), 25; Angela Trentacoste, Ariadna Nieto-Espinet, and Silvia Valenzuela-Lamas, "Pre-Roman improvements to agricultural production: Evidence from livestock husbandry in late prehistoric Italy," *PLOS ONE*, XIII (2018), e0208109; De Grossi Mazzorin and Minniti 2017; Angela Trentacoste, "Fodder for change: animals, urbanisation, and socio-economic transformation in protohistoric Italy," *Theoretical Roman Archaeology Journal* III (2020).

[28] Nicola Terrenato and Jeffrey Becker, eds. *Roman Republican Villas* (Michigan, 2011); for demography and climate, Andrew Bevan et al. "Holocene fluctuations in human population demonstrate repeated links to food production and climate," *Proceedings of the National Academy of Sciences* (2017).

[29] For full discussion and a list of surveys considered with bibliography, see J. Troy Samuels, *Recovering Rural Non-Elites: Commoner Landscapes and Rural Infill in the Roman Middle Republic* (PhD

dissertation, 2019); for the relationship between surface scatters, subsurface archaeology, and demography, see Kim Bowes, *The Roman Peasant Project, 2009-2014: Excavating the Roman Poor* (Philadelphia, 2021).

[30] Cf. Helen Patterson, *Bridging the Tiber: Approaches to Regional Archaeology in the Middle Tiber Valley* (Rome, 2004).

[31] A selection of relevant literature for the environmental history of Etruria includes Laura Sadori et al. "Archaeobotany in Italian ancient Roman harbours," *Review of Palaeobotany and Palynology*, CCXVIII (2015), 217-230; David Kaniewski et al. "Holocene evolution of Portus Pisanus, the lost harbour of Pisa," *Scientific Reports* VIII (2015), 1-14; Mauro Buonincontri et al. "The problem of the alternating dominance of deciduous and evergreen vegetation: archaeo-anthracological data from Northern Maremma," *Annali di Botanica* III (2018), 165-171; Marta Mariotti Lippi, et al. "Plant remains in an Etruscan-Roman well at Cetamura del Chianti, Italy," *Archaeological and Anthropological Sciences*, XII (2020), 1-18. For early charcoal selection and the impact of fuel use as legible in the pollen record, see Marta Mariotti Lippi, et al. "Studi sulla vegetazione attuale e passata della Toscana meridionale (Follonica—Italia) e considerazioni sull'impatto ambientale dell'attività metallurgica etrusca nel VI—V secolo a.C." *Webbia*, LV (2013), 279-295.

[32] Marco Benvenuti et al. "Late-Holocene catastrophic floods in the terminal Arno River (Pisa, Central Italy) from the story of a Roman riverine harbour," *The Holocene*, XVI (2006), 863-876; Marta Mariotti Lippi et al., "Pollen analysis of the ship site of Pisa San Rossore, Tuscany, Italy: the implications for catastrophic hydrological events and climatic change during the late Holocene," *Vegetation History and Archaeobotany*, XVI (2007), 453-465; Marco Benvenuti et al. "Floods, mudflows, landslides: adaptation of Etruscan–Roman communities to hydrogeological hazards in the Arno River catchment (Tuscany, Central Italy)," in I. Peter Martini and Ward Chesworth, eds. *Landscapes and Societies* (Dordrecht, 2010), 187-201.

[33] For the social and economic dimensions of marginality, see Jacob H. Hollander, "The Concept of Marginal Rent." *The Quarterly Journal of Economics* IX (1895), 175–87; Shujiang Kang et al. "Marginal Lands: Concept, Assessment and Management." *Journal of Agricultural Science* V (2013), 129-39. The specific historical relationship between landholding and citizenship in the Roman Republic is well illustrated by Roselaar (2011).

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