War, Food, Climate Change and the Decline of the Roman Empire

*“We historians are extremely uncomfortable with the idea that natural forces in some way circumscribe human agency. Fearful of being labeled ‘environmental determinists’, we opt for a model of change in which all of the significant causal agents in historical processes are internal – or endogenous – to human culture, society, and economy.”*

John L. Brooke[[1]](#footnote-1)

**Introduction**

In 1984, the German ancient historian Alexander Demandt listed over two hundred causes of the decline of the Roman world that had been proposed in previous scholarship.[[2]](#footnote-2) The list offers a clear illustration of the fact that our views of the past are very much determined by contemporary concerns. Famously, Edward Gibbon, child of the enlightenment, blamed the weakening of the Roman Empire on its Christianization. A century ago, in his *Geschichte des Untergangs der antiken Welt*, Otto Seek propagated racial degeneration as a fundamental cause of the fall of Rome[[3]](#footnote-3), while in recent years the failure to prevent the massive influx of foreigners who did not share Roman values has gained unfortunate prominence in non-academic circles.

Climate was already among the causes listed in 1984, but seems to have gained in importance in recent decades, which is no surprise in view of the present-day debates on Global Warming. A team led by McCormick (2012) explained the divergent paths of the eastern and western halves of the Late Roman Empire by different climatic trends.[[4]](#footnote-4) In his wide-ranging monograph *Climate Change and the Course of Global History* (2014), Brooke attributed Roman decline to the triad of warfare, epidemic disease and climate change. Most recently, Harper (2017) has published an ambitious study of the fall of the Roman Empire which emphasizes the pivotal forces of pandemics and climate change. “The fate of Rome was played out by emperors and barbarians, senators and generals, soldiers and slaves. But it was equally decided by bacteria and viruses, volcanoes and solar cycles.” “The hard question has become not whether, but how, to insert the influences of the natural environment into the sequence of cause and effect.”[[5]](#footnote-5) While not losing sight of endogenous political, administrative, economic and military decline, Harper assigns a determining role to the natural forces of disease and climate. If the empire lost its resilience through societal changes, adverse environmental conditions are ultimately to blame. The pendulum clearly has swung in the direction of environmental forces.

Let me state at the outset that I remain a bit skeptical about theories that explain complex societal processes, like the decline and fall of the Roman Empire, largely if not solely by natural forces. This paper is headed by a quote from John Brooke that highlights the contrast between endogenous and exogenous factors, between human agency and the environment. Brooke ascribes an inherent, even intuitive tendency to historians to favor human agency over natural forces in the process of change in human societies. Are “we historians” indeed handicapped by this blind spot in our perception, as Brooke suggests? Are we disinclined to accept the subjection of human history to exogenous natural forces, as the axioms of our discipline tend to focus on the human side? I think not. Some historians remain skeptical regarding grand narratives that favor natural forces over all others, because they think that human societies were too complex to be determined by one or even a few causes.[[6]](#footnote-6)

I will try to make a contribution to this debate by zooming in on the decline of the Roman world, which surely is an instructive case in view of the recent studies that emphasize the key role of epidemics and climate change. The paper is structured as follows: first, the data show regionally different chronologies in developments of economic complexity and population size, which explanations of rise and decline should take into account. The next section addresses fundamental weaknesses of models that view climatic shifts as more or less sole determinants of societal processes, followed by general considerations regarding paleoclimatic proxy data and their interpretation: scholars remain divided regarding the severity of climatic changes in the first millennium AD, in particular compared to more severe changes in the second millennium AD. In contrast to short-term consequences of volcanic eruptions, long-term climate change manifested itself in regionally highly variable shifts in averages of temperatures and precipitation and in patterns of weather extremes, not in distinct and clear-cut climatic optimums and ‘dark ages’. Next, it is argued that the impact of changes in temperature and precipitation on landscape and agricultural productivity are much more diverse and complex than is intuitively assumed in some of the recent studies. Moreover, the detrimental impact of climate change on imperial grain resources that is supposed to underlie the so-called Crisis of the Third Century is not born out by the military and political events. This section is ended by an overview of regional case-studies that show that climatic changes potentially played a role in societal processes, but only among economic and political factors, and that regional chronologies of decline and expansion often do not adhere to paleoclimatic shifts.

The final section is based on the principle that the capacity for resilience of a society to deal with its adverse circumstances is at least as important as climate-related environmental changes. In other words, we should focus on the institutional ability of a society to respond to harvest shocks. In the West, the economic boom of the early Roman Empire rested largely on the positive impact of the state on commercial channels and on the role of urban elites to alleviate the effects of harvest shocks. The weakening of both institutional factors caused the economy to spiral downwards, with detrimental effects on population levels. At the same time, lesser dependence on the state and more stable political and urban institutions supported continued economic complexity, prosperity and population levels in Africa and the East. In short, it is argued that more than adverse trends in temperature and precipitation sapping imperial Rome from its resilience, it was actually changes in society that lowered its resilience and its ability to cope with adverse circumstances.[[7]](#footnote-7)

**Chronologies of decline in the Roman Empire**

Recent studies link climate change to economic performance and population, so we have at least to sketch the course of economic and demographic decline in the Roman world before we can turn to the fundamental causes. Two general remarks must be made at the outset: first, we cannot measure population or the size of the economy in absolute figures. We can only see relative change, which can be supported by very rough estimates. While most scholars broadly agree on the trends, there is wide disagreement on the estimates. Second, the trends do not show the same chronology in all parts of the Roman Empire. Hence, models explaining decline should be able to explain the chronological differences too.

Archaeology in combination with textual evidence shows that both population and urbanization grew from the early first millennium BC onwards.[[8]](#footnote-8) Settlements became more numerous and larger; urbanization spread over a larger territory; the exploitation of the countryside intensified. Roman conquest introduced towns and cities in western and central Europe at the beginning of the common era. In the western provinces, these trends ended around the turn of the second to the third century AD. Most towns and cities dwindled, as did the exploitation of land and natural resources. It is difficult, though, to translate changes in material remains into absolute population figures, as the reduction of economic complexity from the third century onwards made people simply less visible to archaeological studies. Counting ‘sites’ is not the same as counting people.[[9]](#footnote-9) Despite these caveats, it is clear that in northern Africa, population and urbanization reached their peak in the fourth century, while in most of the eastern provinces population seem to have continued to grow until the sixth century, while the cities and rural activities show no signs of decline. However, we should realize that on the regional level there can be significant differences. For example, archaeology reveals a prosperous society in the city of Trier (Augusta Treverorum) and its hinterland in the fourth century AD, while at the same time the archaeological picture is bleak in the rest of northern and central Gaul, where towns, villas and villages gradually vanished.[[10]](#footnote-10) Nevertheless, in general terms we may speak of broadly similar trajectories within the western provinces. The same goes for northern Africa and the eastern provinces.

There is no clear trend break in economic performance that is valid for the entire Roman world, even though some of the proxy data used over the past decades may give this impression.[[11]](#footnote-11) With the attempt to move the debate on the Roman economy onto a firm, quantitative footing, scholars turned to proxies of the size of the economy. Lead pollution in the Greenland ice-core and shipwrecks along Roman shores seem to show a peak in the late first, early second century AD. The significance of these graphs as indicators of economic performance has been overrated. The rapidly declining number of shipwrecks may be caused partly by the shifting of shipping routes away from the much-explored Mediterranean coasts of Spain, France and Italy to less investigated shores. Moreover, later wrecks are less visible due to the increasing use of barrels instead of amphorae over the course of the imperial period.[[12]](#footnote-12) In other words, the shipwreck graphs do not contradict continuing trade in northern Africa and the East. The lead pollution peak may reflect a peak in silver extraction in the Roman Empire, in particular Spain, but it is quite uncertain how this relates to overall economic performance rather than the functioning of the state. Other proxies, such as the number of public building projects and animal bones indicating meat consumption, are unreliable and show wide diversity throughout the empire.[[13]](#footnote-13) On the other hand, we may observe that in the early empire (first and second centuries AD) the scale of trade, the aggregate volume of artisan production (although always characterized by relative small-scale production methods) and the number of imported goods at urban and rural sites increased. The archaeological presence of non-essential goods that were sufficiently valuable to ensure a reasonable profit-margin, but not too expensive to exclude a wide market (i.e. goods like textiles, glass and fine pottery), is a good indicator of economic performance.[[14]](#footnote-14) Such consumption-related markers of economic performance show decline in the western provinces in the third century AD, in Africa after the fourth, and in most of the eastern provinces continued prosperity until the sixth century. In sum, if we are looking for fundamental causes of economic and demographic decline in the Roman world, these must be able to explain the different chronologies in the various parts of the empire.

**Climatic Optimums and societal ‘efflorescences’**

Until recently, books were still written on the fall of the Roman Empire that ignored climate as a noteworthy factor. In 2013, archaeologist Esmonde Cleary published his study of the Roman West between AD 200 and 500, discussing the role of the military, the urban elites, the economy, Christianity, the ‘barbarians’ – but not climate. No serious study will do so in the near future, as several influential publications recently propose climate change in the ancient world as a main factor in the rise and decline of the Roman Empire.[[15]](#footnote-15) In an article written by a collective of historians, archaeologists and paleoclimatologists led by Michael McCormick, we read: “The favorable and exceptionally stable [climatic] conditions that prevailed across the Roman Empire from c. AD 100 BC to c. 200 probably fostered the Empire’s unparalleled rise.”[[16]](#footnote-16) Climatic stability, it is emphasized, came to an end between AD 150-200, i.e. at a time of economic, political and military stress. After ca. AD 400, the variability in the climate increased in the West, with colder and wetter conditions. In the West, precipitation dropped sharply in the first half of the sixth century, while in the fourth or fifth century, wetter conditions returned for two centuries to at least major parts of the East. Hence, it is concluded, climatic conditions may help to explain the success of the Eastern Empire while the Roman Empire failed in the West.

Although Sturt Manning is less bold in his reconstruction of climate change patterns, he too assigns a vital role to climatic conditions in bringing about the demise of the Roman world. During the Roman Optimum, from the second century BC to the second century AD, warm and humid climatic conditions in the Roman Empire reduced the risks to farmers and brought stability, offering the conditions for agricultural and demographic expansion. With the end of the Roman Optimum, however, agricultural uncertainty increased and bad years became more frequent. Central and northern Europe saw less favorable conditions arrive earlier than the East, which offers, so Manning suggests, an explanation for the divergent trajectories of the Eastern and Western Empires.[[17]](#footnote-17)

The explanation of John Brooke is less straightforward. In his view, the two exogenous factors of climate change and virgin-soil epidemics were decisive in bringing about the end of the Roman world. However, he notes that significant changes in the climate came too late to explain the beginning of economic decline, which in his view was primarily caused by the Antonine Plague, in combination with warfare. It is only at a later stage, in the sixth century, that severe and adverse climate change, partly triggered by volcanic eruptions, was added to warfare and epidemic to form a devastating triad that caused the fall of the Roman Empire.[[18]](#footnote-18) Nevertheless, Brooke also argues that climatic reversal around AD 300 – bringing colder, wetter weather south through Europe – undermined what he calls the imperial agro-economy,[[19]](#footnote-19) while increasingly frequent drought in central Asia in the fourth century set peoples like Germanic tribes, Goths and Huns in motion, which embroiled the Roman world in a military struggle that the western empire would not survive.[[20]](#footnote-20)

Being a member of McCormick’s team, it is not surprising that Harper’s reconstruction of climate change overlaps largely with the earlier study, but he offers a much clearer overview of climatic phases and their impact. The Roman Climate Optimum is said to have ended in the mid-second century AD. The third century is seen as colder and drier, droughts being mentioned in Christian and rabbinic literature.[[21]](#footnote-21) The fourth is warmer again, more benevolent, but instable and fluttering.[[22]](#footnote-22) The major climatic downswing occurred in the sixth century, when solar activity declined, coinciding with volcanic eruptions around AD 540.[[23]](#footnote-23)

In view of the temporal coincidence of human events and ecological trends, it is tempting to see the Roman Optimum as fundamental to the rise of the Roman Empire, and the same goes for the coincidence of the Bronze Age Optimum and the emergence of the Near Eastern palace economies, or the Medieval Optimum and the population growth of the 11th and 12th centuries.[[24]](#footnote-24) Following the same logic, the intermediate solar minima are seen as fundamental causes of societal decline (e.g. the pre-classical crisis starting around 1200 BC violently leading into the Iron Age[[25]](#footnote-25), or the early-modern Little Ice Age causing famine, revolt and war in the long 17th century). In such models, human societies over the past millennia have been passive subjects of exogenous forces, only recently making sufficient institutional and technological progress to overcome the forces of nature (and even provoke them!).

Harper’s climatic phases (quotes from pp. 14-15):

1. Roman Climate Optimum (AD 200 BC–150): “… an inviting moment to make an agrarian empire out of a pyramid of political and economic bargains”
2. Roman Transitional Period (AD 150–450): “one of the most dramatic sequences of climate change”; “climate instability pressed on the empire’s reserves of strength and intervened dramatically in the course of events”
3. Late Antique Little Ice Age (AD 450–700): “the deterioration of the physical climate coincided with unprecedented biological catastrophe to overwhelm what was left of the Roman state”

Brooke makes the broad claim that the classical empires of the Old World were shaped by the Classical (Roman) Optimum running between the pre-classical crisis (ending variously 800/600 BC) and the cold episode of the Dark Ages (beginning AD 300/600),[[26]](#footnote-26) but he does not attempt to offer a model that clarifies the role of climate change in the course of global history.[[27]](#footnote-27) The most explicit model of causality in his book pertains to China in the first millennium AD, which may be due to the convenience of being able to relate strong/weak monsoons to the presence/absence of Chinese political unity and the fate of particular dynasties. There appears a tendency of climatic stability to coincide with political unity and dynastic stability, while floods or droughts are linked to rebellions and dynastic upheavals.[[28]](#footnote-28) Interestingly, the cooling of the northern hemisphere around AD 300, which ended the Roman Optimum, is linked to the first proto-states emerging in Korea and Japan,[[29]](#footnote-29) which leads one to question why the same trend is used to explain the rise of states on the one end of the Eurasian continent and the decline of the Roman state on the other. Reference to bad harvests and rebellions seem sufficient to link the explanation for the fall of empires to the climate, although one could just as well argue that larger states, controlling a larger and more diverse territory, would be more successful in coping with increasing harvest volatility than smaller states.

It also remains unclear how the rise of Rome is linked to the climatic optimum that is said to have begun sometime during the mid-Republic. The expansion of Rome clearly was at the cost of opponents both within Italy and the wider Mediterranean that experienced the same favorable conditions as Rome. Brooke points out that archaeological surveys have revealed the growing habitation in the countryside in Italy and the intensification of its exploitation from the third century onwards.[[30]](#footnote-30) This development may be linked to improving weather conditions, but also to the continued growth of the population, which had begun centuries before the Roman Climatic Optimum, and to the ‘pacification’ of the peninsula in the wake of Roman conquest, which allowed a more dispersed settlement pattern in lowland areas.

Phenomena that do not nicely fit the chronological picture are often ignored.[[31]](#footnote-31) The archaeology of Greece has for instance shown that its population started to grow from the beginning of the first millennium BC, intensifying in the 8th century BC. This period of demographic growth coincided with the pre-classical crisis, a solar minimum that began with the demise of the Minoan and Mycenaean civilization and that is said to have lasted until 700/600 BC, with peak solar minima centering around 750 BC.[[32]](#footnote-32) In other words, population increased, new poleis founded, and settlements on the Greek mainland expanded into marginal lands precisely when climatic conditions were at their poorest. The point is not that there is no link between climate and society, but that we should avoid easy assumptions about causal links between the two. Before we zoom in on various regions in the Roman Empire in the first millennium AD, I will address some general issues concerning the impact of climate change on Roman society.

**Climate change: some general considerations**

Since we have no direct data on either temperature or precipitation for the premodern world, paleoclimatic research relies on different proxies that range from the chemical characteristics of Greenland ice or stalagmites, to width of tree-rings, water-level and sediments of lakes, etc.[[33]](#footnote-33) Paleoclimatologists emphasize that many indicators can only be dated within a margin of up to several decades, with absolute dates (as in the case of ice cores) calibrated on the basis of linking patterns to datable events, such as volcanic eruptions. The proxies directly relevant to the Mediterranean world, such as speleothems and lake sediments, show uncertainties and wide margins, though, and this is the more the case the further one goes back in history.[[34]](#footnote-34) Tree-rings are precisely datable, but the Mediterranean world offers less useful dendrological data than for example central Europe. Many proxies for the ancient world offer insufficient resolution to link them to short-term societal events.[[35]](#footnote-35)

Particularly risky is the combination of natural proxies and textual evidence, the more so when ancient written sources are primarily used to confirm hypotheses based on natural proxies. The problem is not so much that ancient writers tend to pay more attention to extremes than to normality, but the reference to flooding or drought is also not random. To begin with, the coverage of literary sources is not geographically or chronologically even. Certain times and places are covered better in the extent texts than others. For the mid- and late Empire, we have more sources on Palestine, for example, than on Greece, so droughts are mentioned more often for the first region than for the latter. Moreover, in ancient thought, natural disasters are linked to the condition of the times, which are perceived as affected by the gods and the actions of rulers.[[36]](#footnote-36) Hence, writers writing from a perspective of gloom and disaster will naturally tend to mention not only drought and drought-induced famine, but also locusts, diseases among man and animals, and unexplainable phenomena. Harper too warns that Christian writers pay more attention to phenomena like poverty and hunger, as these are linked to the role the church played in alleviating hardship. Moreover, the geographical focus of Christian texts is different from that of earlier writers.[[37]](#footnote-37) In sum, the frequency with which extremes in weather are mentioned in our literary sources is a very uncertain indicator of climate change, and there is a great danger of circular reasoning, as political unrest may lead to more mention of extreme weather.[[38]](#footnote-38) Just as early-modern paintings of wintery landscapes or ice-skating Dutchmen do not prove the Little Ice Age, literary accounts of extreme weather cannot serve as evidence of climate change in Antiquity.

The labels of “Roman” or “Medieval Optimum”, described as eras of stable and warm climate, conjure up the image of centuries of endless good weather, with the reverse during the intermediate periods of climatic crisis (“Dark Ages”, “Little Ice Age”). The image is sometimes made explicit in phrases like “two centuries of severe drought” (Brooke, referring to 3200-3000 BC).[[39]](#footnote-39) There is a tendency to focus on extreme weather phenomena during periods in which they are expected. Brooke and Harper, for example, emphasize the droughts in fourth-century Palestine, but fail to notice severe drought in the same region in the early imperial period, i.e. during the Roman Optimum, even though Flavius Josephus (AD 37 – c. 100) notes several widespread droughts that affected both Judaea and its neighboring regions.[[40]](#footnote-40) Annual fluctuations within a limited, regionally determined range of temperature and precipitation characterized all periods. This is best illustrated regarding the second half of the second millennium AD, a period on which we have fairly secure data. The graphs based on these data show wild annual fluctuations. The concept of climatic change refers to trends in these wild and seemingly random fluctuations, but these trends are far from apparent and readily discernible. In fact, the economic historians Kelly and ÓGráda have argued that there is actually no such trend as the ‘Little Ice Age’. Regarding a reconstruction of annual German temperatures from AD 1000 they observe that “the proportion of good and bad years has remained constant, as has the probability of two good or bad years in a row”. In their view, the LIA is the result of statistical manipulation and not really present in the annual fluctuations of temperature and precipitation.[[41]](#footnote-41) While this goes too far, their criticism demonstrates that climate change is a matter of shifts in wildly fluctuating variables. There have never been eras of good or bad weather. Harper makes the same point when he says that sharp climatic variability also occurred during the Roman Climatic Optimum, which at most moderated the excesses of year-to-year unpredictability.[[42]](#footnote-42)

It is increasingly becoming clear, moreover, that there are significant spatial variations within larger-scale or global patterns.[[43]](#footnote-43) Harper too notes that, while changes in temperature tend to be coherent over a wider area, precipitation shows a regionally very incoherent pattern.[[44]](#footnote-44) This severely weakens the argument regarding the climatic causes of the different fate of the East and West in Late Antiquity, which is primarily based on generalizations concerning climatic change in the eastern and western halves of the Mediterranean region.

The limitations of generalizations concerning climate change also explain why the climatic periods used in the above studies do not seem to have clear temporal boundaries, which is exacerbated by the fact that many proxies cannot be dated precisely.[[45]](#footnote-45) In view of the nature of the evidence and of climatic trends, this is reasonable and inevitable. In Harper’s apt expression, the climate proxies form a “cacophony of voices”.[[46]](#footnote-46) However, this realization has severe methodological implications, in particular because many processes within human society are just as difficult to pin down. The emergence of states in the Near East or the decline of the Roman state cannot be dated to one year or decade, possibly not even to one century. So, while chronological coincidence seems to be the main basis for the assumed causal link, there is a danger that the coincidence of human events and climatic trends is the outcome of the observer’s selection rather than that it is present in the data. This makes claims regarding the causal link between processes in human society and climate both difficult to confirm and refute.

Some scholars may rightly point out that some climatic events are clearly discernible in the proxies and in the statistical trends. Some years stand out in the data as exceptionally cold, sometimes with textual confirmation that the weather was dark and gloomy in those years. Indeed, we have to make a distinction between long-term shifts and short-term phenomena caused by volcanic eruptions. The latter on many occasions, clearly visible after the development of modern meteorology, cause abrupt changes in the weather, for example triggering cold and dark summers for a couple of years.[[47]](#footnote-47) The correlation between volcanic eruptions and the extent to which the Nile rose is made clear for the Ptolemaic period, as is the causal link between the frequent and repeated failure of harvest failure in Egypt and political and social unrest.[[48]](#footnote-48) Climatic events in the wake of volcanic eruptions are severe, abrupt, but also short-lived. European summer temperatures, for example, show a cooling due to volcanic events that is “strongest in the first and second year after the eruptions. The average anomalies are of the order of 0,5 oC.”[[49]](#footnote-49) Longer-term events, on the scale of the Roman Optimum and the Dark Ages, are much more gradual, only noticeable in the subtle shift of averages and the frequency of extremes. For our estimation of the impact of climate on societal change, this is an important distinction, as volcanic eruptions may have an immediate, short-lived impact, but they do not adhere to wider trends and have no direct long-term consequences, while gradual long-term climatic changes occur on a time-scale that allows societies to adapt in ways that may even have been imperceptible to the peoples involved.[[50]](#footnote-50)

Last , but not least, some of the scholars mentioned above agree that the climate change following the Roman Optimum was relatively limited. Brooke does not count the late antique Little Ice Age (i.e. the early medieval climatic depression) among the major late-Holocene climatic ‘lows’, in contrast to the Pre-classical crisis of the late Bronze Age/early Iron age, or the Little Ice Age of the early-modern period. McCormick stresses that the various proxies indicate a low degree of variability between 100 BC and AD 800, while S. Manning observes that the changes in the 1st millennium AD were not of the same intensity as the changes of the 2nd millennium AD (i.e. the Medieval Optimum followed by the early-modern Little Ice Age).[[51]](#footnote-51) In the present state of paleoclimatic research, the shifting trends regarding temperature and precipitation affecting the Roman world seem to have been relatively limited and not of the same intensity as the recent man-made global warming.[[52]](#footnote-52) This is important to keep in mind when judging the impact of climate change on society in this period.

**The impact on landscape and agriculture**

In an overwhelmingly agricultural society, Hin wrote in her chapter on the beneficial impact of climate on the expansion of republican Rome, “climatic development may be regarded as a relatively pure indicator of economic development”.[[53]](#footnote-53) I wonder whether that is the case. The weather undeniably plays a crucial role in inter-annual fluctuations of agricultural production, and gradual long-term changes in the pattern of temperature and precipitation caused transformations in landscape and agriculture, and hence potentially also in food supply and diet.[[54]](#footnote-54) However, climate change is claimed to have a much more fundamental impact on human society. In 2013, the economic historian Paolo Malanima wrote that “climatic phases marked the past history of mankind. […] While warm periods were favorable to the spread of cultivation and the multiplication of humankind, cold epochs coincided with periods of demographic decline. Roman civilization flourished in a period of warm climate and was accompanied by population increase, while the early Middle Ages was an age of demographic decline and cold climate.” He continued by observing that periods of warm climate allowed the expansion of cultivation into higher altitudes and increased population, since the volume of energy was rising. Hence, “the size of the population that could be fed increased remarkably.”[[55]](#footnote-55) In other words, warmer periods increased the carrying capacity of the land and thus allowed populations to grow and prosper, while colder periods exactly did the opposite. The balance between land and population brings us back to Malthusian pressure, with the added element that climate change means that not only population is a varying factor, but that also the carrying capacity of the land varies independently of human action.

Harper uses the same argument when he writes: “In hilly Italy, an extended rise of 1oC would have rendered, on conservative assumptions, an additional 5 million hectares of land suitable for arable cultivation; that is enough land to feed 3-4 million *hungry* bodies” [my italics].[[56]](#footnote-56) In other words, a warming of the climate increased the total arable and thereby the carrying capacity of the land, and the reverse happened with a cooling down of the climate. Harper’s adverb ‘hungry’ is meaningful, as it implies that the population is (constantly?) in desperate need of more land. Hence, more arable feeds more people, less land feeds less people, and so we are back to Malthus. And while Brooke says that overpopulation was not a fundamental problem of premodern times, he does state that “efflorescences of ancient and medieval economies were limited to epochs of climatic optimum”[[57]](#footnote-57), i.e. when good weather loosened Malthusian pressure.

The argument of Malanima and Harper is based on the wrong assumption that the population level is determined by the carrying capacity of the land (the latter being a concept of limited usefulness to begin with). One may distinguish between the potential carrying capacity of the land and the realized one. A calculation of the potential production of the arable and other land based on the technological level of agriculture and the current climatic conditions may result in a theoretical figure regarding the potential carrying capacity of a certain region. For example, it has been estimated that Roman Italy could have fed 15-20 million people. This is a quite meaningless figure, as the potential carrying capacity was never realized and the Italian peninsula never counted 15-20 million people before the modern era.[[58]](#footnote-58) Real agricultural production is not only determined by such ecological factors as soil, yields and weather, but also by such societal factors as the structure of landholding, the extent of (under)employment, specialization and market integration.[[59]](#footnote-59) This means that changes in society and economy can alter average total food production (i.e. realized carrying capacity) without any change in ecological conditions. It also means that a long-term worsening of ecological conditions (say, a cooling down of the climate) need not have resulted in a long-term lowering of total food production, if compensated by societal changes in the agricultural economy. This is quite similar to what already Ester Boserup said many decades ago, when she argued that demographic growth would not mean that population levels would hit their head at a Malthusian ceiling, but that the pressure would realize changes in the agricultural systems. And even Malthus himself did not regard the ‘ceiling’ as ecologically fixed and beyond human control. So the above argument does not mean that climate change is not relevant, as it changed the ‘playing field’ for the actors involved, but the impact climate change had, was not solely ecologically determined.[[60]](#footnote-60)

In addition, there is an inherent conflict in Harper’s model, which is based on two factors: on the one hand, the pandemics of the second and third century, and on the other, climate change. Harper agrees that the pandemics were not endogenous events in a Malthusian sense: they were not brought about by population pressure and a lowering of living standards. Following his carrying capacity approach, the Roman population was not near the ‘ceiling’ before the pandemics and was significantly lowered afterwards. Hence, there would have been plenty of scope for a lowering of the ‘ceiling’ due to a cooling down of the climate without causing trouble.[[61]](#footnote-61)

In short, an ecological carrying capacity approach is simplistic and does not bring us forward. It would only make sense if the entire landscape was exploited optimally all the time and that was clearly not the case. Arable land was never used to the full extent and throughout the pre-industrial era there was always room for the intensification of the exploitation of the land.

The impact of changes in temperature and precipitation are much more diverse and complex than more or less intuitively assumed in some of the recent studies.[[62]](#footnote-62) Cereals and pulses were the staple foods of the Roman world and the fluctuations in temperature remained well within the range of growing conditions of the main crops. Though ecologically optimal conditions for each crop/(sub)species can be defined, most plants do just fine within a wider range of conditions, ensuring some resilience against minor fluctuations.[[63]](#footnote-63)

In contrast, Malanima summarized the ecological consequences of an enduring 1oC drop in temperature more dramatically: in the temperate zones of central Europe, the concomitant reduction in yearly hours of sunlight would decrease the growing period for crops, pastures and forests by approximately three weeks. In cold northern European regions, cereal production would become more difficult, while the marginal frontier of land was lowered by 150-200 meters.[[64]](#footnote-64) Naturally, a rise in hours of sunlight and temperature would have a reverse effect. Similarly, Brooke argues that the warmer conditions of the Roman Optimum favored the grain and wine economy of Mediterranean and allowed its expansion northwards. In mountainous regions, changes in temperature probably caused the movement of agricultural cropping zones up or down the mountain slopes.

However, climate change has the greatest impact where conditions of temperature and precipitation are on the margins of biological requirements, such as on the fringes of deserts or on mountain slopes, and on crops that are sensitive to temperature and precipitation, such as the olive, grapes or walnuts. The consequences of a reduction in yearly hours of sunlight, which are summarized by Malanima for temperate zones,[[65]](#footnote-65) were different in much of the Mediterranean lowlands, where the growing cycle of cereals and most other crops was determined by the avoidance of the hot and dry summer months, not by the lack of warmth and sunlight in the rest of the year. The agricultural handbooks of Cato, Varro and Columella tell us that, apart from farm land at higher altitudes, crops should be sown sufficiently early to avoid the summer heat and drought. In many parts of Italy, wheat was sown in autumn and harvested in May or June. Hence, it is unlikely that in much of the Mediterranean lands there would be a detrimental effect of the reduction of sunlight in the form of the shortening of the annual growing period. As the agricultural writers emphasize, things were different in the mountain valleys, where crops were sown in the springtime in order to avoid the cold and heavy rainfall of winter. Regarding precipitation, the situation is equally varied. In much of the Mediterranean lands, an increase in average levels of rainfall might be beneficial to agriculture, if it occurred in the right time of the year and not in the form of torrential rainfall that would do more harm than good. On the other hand, more rain was potentially harmful on the farmland in higher altitudes, in particular on the western side of the mountain ranges of Italy and Greece, as depressions generally went from West to East and precipitation was highest on the western side of mountain ranges. In short, in a highly varied geography as the Mediterranean region, the relationship between climate and environment differs even at a local level.[[66]](#footnote-66)

Moreover, it is difficult, if not impossible, to distinguish archaeologically the transformations in the landscape that were the result of variations in the climate from changes in the exploitation of the countryside.[[67]](#footnote-67) A few examples corroborate the point. Wine production in the Moselle region peaked in the 4th century, but this had little to do with climate (after all, we are far beyond the so-called Roman Optimum). Instead, it is related to the booming market in the city of Trier, which became the imperial residence at the end of the 3rd century, and its hinterland.[[68]](#footnote-68) In some parts of Italy and southern Gaul, moreover, we see an increase of marshes and wetlands in Late Antiquity and the early Middle Ages, which may be ascribed either to increasing precipitation or to a neglect of drainage works by landowners and authorities.[[69]](#footnote-69) Imperial Rome had created a huge and prosperous market for capital- and labor-intensive farms in its hinterland. The so-called suburbium was therefore densely populated and well-drained. When Rome’s imperial grandness had disappeared and its population shrunken disastrously during the wars of the sixth century, its hinterland became depopulated and malaria-infested marshes returned. This is not to deny the importance of changes in the landscape, but only to make the point that it is nearly impossible to separate and assess the role of ecological and societal conditions on the basis of archaeological evidence. Similarly, a reduction in agricultural activities in some marginal lands may be either the result of increasing drought or of the decline of irrigation. Shifts in markets and trade routes and in landownership affected the exploitation of the countryside, which made investment in irrigation worthwhile or not. This also means that, depending on social or economic conditions, adverse trends in the climate might have been compensated by increasing drainage or irrigation, or by the adaptation of cropping strategies. In sum, it is impossible to generalize, as Brooke does, that colder and wetter weather arriving in the Mediterranean lands after the Roman Optimum would be damaging to agriculture there. The same trend might have beneficial or detrimental effects – or few at all – dependent on the geographical conditions, and these might differ not only between regions, but also very locally, depending on altitude, soil, west or east direction, and so forth. Moreover, climate was an important factor in the exploitation of the countryside, but it was a factor among others, which, in the case of long-term change, offered some scope for adaptation to farmers and society at large.

**Climate and imperial crisis**

The study by McCormick et al. explicitly ascribes the empire-wide upheaval of the third century to climatic forces. Between AD 235 and 285 – i.e. the period of the so-called soldier-emperors, during which the Roman Empire saw almost endless civil war and the weakening of the central imperial authority in Rome – three to five major volcanic eruptions are said to have disrupted the food production within the empire. The fate of the empire is particularly linked to the Nile floods on which the grain harvests in Egypt, “the Roman Empire’s breadbasket”, depended.[[70]](#footnote-70) Egypt, it is argued, saw more abundant floods during the early empire (until 155 AD) than between AD 155 and 299: “When the empire was at its zenith and the great grain fleets sailed north every year to the feed the capital and swell the cereal resources of the Empire, Egypt’s productive farms seem to have enjoyed better Nile floods and therefore better harvests and fewer failed harvests.”[[71]](#footnote-71) The implied link is not born out by a closer look at the economic and political situation. It would go too far to discuss the role of Egypt’s grain in the functioning of the Roman Empire in detail here, but a few remarks may be made.

To begin with, the role of Egypt in feeding the empire is grossly exaggerated, for example by Harper when he writes: “In strained circumstances the Empire could rely on Egypt.”[[72]](#footnote-72) Indeed, the tax-grain collected in Egypt was vital for the food supply of the capital, and also served to provision the troops, primarily in the Eastern provinces, and most likely some of the Mediterranean naval crews. However, while the nature of the evidence does not allow precise estimates, it is very unlikely that Egyptian exports contributed significantly to other outside demands. Rough estimates of the total volume of grain collected by the Roman state in Egypt in the early empire vary between 5 million *artabae* (Rathbone), 6 million (Bowman), 9 million (Sharp) and 17.5 million (Duncan-Jones).[[73]](#footnote-73) Sharp’s figure is based on reasonable estimates of total acreage of arable land, the proportion of public and private land and average tax rates. Though not claiming any exactitude, 9 million *artabae* or about 30 million *modii* seems in the right order of magnitude for most years. Egypt is consistently mentioned as the main supplier of the city of Rome.[[74]](#footnote-74) Hence, while Africa, the other “bread basket” of the Roman Empire, contributed significantly to the total demand of Rome, as did Sardinia and Italy, the lion’s share of grain consumed in Rome must have come from Egypt. I have argued elsewhere that the tax-grain controlled by the *annona* was not only used on behalf of the *plebs* *frumentaria* (probably about 12 million *modii* annually), but that the authorities sold on top of that large amounts of grain to the bakers who supplied the city.[[75]](#footnote-75) On a conservative estimate (3,5 *modii* per month), the estimated one million inhabitants in the capital consumed 42 million *modii* of grain annually. Real requirements must have been significantly higher, due to spoilage during transportation and storage and losses due to fire and floods in Rome. [[76]](#footnote-76) So, the real figure must be closer to 50 million *modii*, much – and probably, most – of which consisted of Egyptian tax grain. It is impossible to estimate with any exactitude the number of people in the Roman armies and fleets (including the troops that were stationed in Egypt, the crews of boats patrolling the Nile, workers in mines and quarries, etc.) who were provisioned with Egyptian tax-grain, let alone the spoilage involved in military logistics (which in pre-modern days was huge[[77]](#footnote-77)), but if Sharp’s estimate is indeed in the right order of magnitude, the contribution that Egypt could make to other outside demands was relatively small.

This is corroborated by the evidence concerning the supply of Egyptian state-grain to local rulers. The Roman authorities occasionally made Egyptian tax-grain available to the communities in the eastern provinces, but the sources stress the exceptionality of these contributions. In grand acts of benevolence, surplus grain was made available - against payment, though – to cities and vassal rulers in the eastern provinces. As a non-identified second-century emperor stated in a letter to the Ephesians: “It is clear that you will make prudent use of this agreement, bearing in mind the necessity that first the imperial city should have a bounteous supply of wheat procured and assembled for its market, and then the other cities may also receive provisions in plenty. If, as we pray, the Nile provides us with a flood of the customary level and a bountiful harvest of wheat is produced among the Egyptians, then you will be among the first after the homeland.”[[78]](#footnote-78) This letter confirms, first, that Egypt’s tax-grain was of prime importance to the provisioning of the capital; second, that allocation was based on status in the eyes of the imperial authorities; third, that communities could not count on Rome’s permission annually.[[79]](#footnote-79) Such contributions start in the reign of Augustus, who turned Egypt into a province: in 24 BC, King Herod the Great bought a large amount of grain from the prefect of Egypt in order to alleviate a famine in his kingdom.[[80]](#footnote-80) Queen Helena of Adiabene did the same during the reign of Claudius.[[81]](#footnote-81) Talmudic sources confirm the occasional import of grain from Egypt.[[82]](#footnote-82) On at least three occasions, the city of Tralleis bought grain from Egypt, in AD 127 amounting to 60,000 *modii*.[[83]](#footnote-83) In the early third century there was even an official in Ephesus who was responsible for the supply of grain from Egypt, but it is unclear whether this was a permanent magistracy or an ad hoc position.[[84]](#footnote-84) Coins from Tarsus indicate that this city received Egyptian grain from Caracalla and from Severus Alexander.[[85]](#footnote-85) Hence, Egyptian grain continued to be made available to the cities of the East under the Severan emperors. Whether these contributions to the cities of the Roman East continued afterwards is difficult to say. On the one hand, most cases are epigraphically attested, so it is possible that the declining number of inscriptions put up by city officials caused the absence of further evidence. On the other hand, the Sassanid takeover of the Parthian Empire during the reign of Severus Alexander intensified the warfare on the eastern frontier, so that military supply may have monopolized Egypt’s remaining tax-grain.

Finally, we have to consider whether there was a significant private export from Egypt. The levy of 10 percent of the crop produced on private land and about 30-40 percent of crops grown on public land left part of the surplus in the hands of Egyptian landowners, but not all of this was available for export. The non-agricultural producers in the countryside and the inhabitants of the larger cities in Egypt, foremost Alexandria itself (with an estimated population of several hundred thousand) depended on Egypt’s surplus production. The papyri regularly mention internal grain trade in Egypt, but rarely exports.[[86]](#footnote-86) In short, our evidence does not allow to establish with any certainty whether surplus was available for private exports, but it is very unlikely that it was on a large scale.

We may conclude that most of Egypt’s tax grain went to Rome and that the remainder had to be shared between the imperial forces and the urban communities in the East. The total consumption of cities in the East exceeded the total grain export of Egypt by far, the more so as imperial requirements were fulfilled first. Even if we assume that in most years 5 million *modii* was made available to urban consumers in the East, at best 125,000 people could be fed from these shipments. Just in order to put this volume into perspective: If, for convenience sake, we assume 25 million inhabitants in the entire Greek East (outside Egypt), that would mean that 0,5% of demand was covered by Egyptian tax-grain. Occasional access to Egypt’s grain may have been a very helpful bonus to particular cities in some years, but in general, these cities lived of their own hinterlands. Again, we cannot rule out that an increased frequency in the failure of the Nile-flood mostly affected the cities of the Greek East, as the central authorities would have taken care of imperial demands first. However, there is no positive evidence for this hypothesis, nor should we assume that this would put the empire in turmoil.

If one postulates (incorrectly, as we have just argued) that Egypt played a vital role as the breadbasket of the empire, it seems obvious that an increase in the frequency of poor Nile floods had serious consequences outside Egypt. Is there any evidence for the hypothesis that more frequent failure of the Nile-flood weakened the Roman state or the urban social fabric in the East? Much of the evidence consists of instances of food shortage or famine. For example, Harper compares the shipment of grain from Sicily to Alexandria during a shortage in Egypt in the early seventh century AD to bringing coal to Newcastle. This figure of speech is suggestive of the remarkability of the situation.[[87]](#footnote-87) Proof would consist of a clear pattern that showed that serious food shortages and famines increased in frequency after the mid-second century or that food supply failures in the rest of the empire were increasingly caused by bad harvests in Egypt. Instead, we find relatively few food shortages and famines in the third century and relatively many in the fourth, even though the fourth century, according to Harper, showed better climatic conditions than the third.[[88]](#footnote-88)

Unfortunately, the nature of the evidence does not allow to argue this way. The frequency of food shortages and famines in our sources is a function of the number and nature of our sources, not of their actual occurrence. As we have seen above, Harper rightly makes this point. Literary sources focus on the political and cultural centers of the Roman world, while death and starvation are not the kind of things that local rulers and patrons would want to advertise engraved in stone. We may safely assume that many more regional shortages, even famines, occurred in the Roman Empire than are mentioned or recognizable as such in our sources. If we have, for example, less instances of grain shortages in the Roman capital in the long third century than from the reign of Augustus to that of Commodus and in the second half of the fourth century, this says something about the sources on Rome during these periods, but little about the food supply of the capital.

Harper, however, claims that “the fourth century presents us with accounts of spatially widespread food crises, of a kind that are hard to find in the earlier days of the empire” and he discusses the food crises of the 380s as a case in point.[[89]](#footnote-89) One of our main sources is Symmachus, at the time city prefect of Rome and in charge of the food supply of the city and hence well-informed.[[90]](#footnote-90) Symmachus observes that in 383 the harvest in all the world had failed. However, Symmachus, who was a pagan at a time when the imperial court and most high officials were Christians, links this disaster to a dispute regarding the Altar of Victory, which had been removed in 382 by the emperor Gratian. Divine dissatisfaction with the treatment of Vestal Virgins and pagan priest, Symmachus claims, had caused harvests to fail and famine to ravage Rome.[[91]](#footnote-91) Not surprisingly, the bishop Ambrose denies that the harvest had been poor in all provinces, though he says that the Nile flood had failed and confirms that people were starving.[[92]](#footnote-92) Symmachus had reason to overstate the widespread nature of the crisis in order to strengthen his point of divine wrath, while Ambrose had reason to downplay the shortage. It is possible that famine and starvation in the provinces failed to draw attention by contemporary writers, but the sources only tell us that severe supply problems occurred in Rome in 383-385 and 388 and in Antioch in 384-385. Increased mortality is mentioned regarding Antioch. The gravity of the situation in Rome is indicated by the mention that people resorted to eating twigs and shrubs and that the authorities dispelled foreigners from the city. To what extent the shortage caused starvation and increased mortality in Rome is impossible to say.

Symmachus blames the shortages in Rome on the combination of bad harvests and failing imports. Already in 382 Symmachus expresses his worries in a letter to the proconsul of Africa: the harvest in Africa in that year had been bad and therefore grain would have to be imported from other provinces.[[93]](#footnote-93) Apparently, also the shipments from Sardinia and Sicily were insufficient to ward off shortage in Rome, as is implied by Prudentius, who some years later counters Symmachus’ argument concerning divine wrath by pointing out that at that time the shipments from Africa, Sicily and Sardinia had arrived on time and that the Nile flood had been normal.[[94]](#footnote-94) So, the crisis of 383 seems to have been caused by insufficient shipments from Rome’s main suppliers at the time: Africa, Sicily, and Sardinia. Regarding the following year, Symmachus complains in his letters that the grain fleet had sailed elsewhere and he urges the emperors to ensure the arrival of African shipments before winter. Finally, he protests against the failure of shipments from Egypt and Spain to appear and the refusal of the Senate to step in. Interestingly, he requests a contribution from the state treasury to end the crisis, which shows that grain was to be had, if at a price.[[95]](#footnote-95) Not only the Christian Ambrose, but also the pagan Ammianus Marcellinus criticizes Symmachus’ measure to dispel foreigners, and Ambrose implies that shipments had merely been delayed by unfavorable winds, while the harvest in Italy had been good.[[96]](#footnote-96)

The problems of 383-385 repeated themselves in 388: harvests failed and grain shipments failed to appear, which may have been linked to the civil war (387-388) between Magnus Maximus in Italy and Theodosius I in the East.[[97]](#footnote-97) But not always did problems end badly: in the following year Symmachus was pleased with the arrival of grain from Macedonia sent by the emperor. He wrote in a letter: “For, as you remember, because of delays in Africa, famine was almost at our doorstep, when our most clement emperor, born for the salvation of all, prevented it, through mobilizing levies from this other area.”[[98]](#footnote-98)

We would like to know whether Rome’s failure to draw help from the East was related to the food shortage that apparently struck the hinterland of Antioch in 384. The orator Libanius is our sole source on the problems and he clearly emphasizes his own role in solving the crisis in Antioch. What seems to have occurred is that many refugees flooded the city when the harvest had failed. Serious mismanagement by a governor who issued a maximum price without being able to ensure sufficient supply aggravated the crisis. The bakers fled the city, only returning when Libanius persuaded them to do so, after which the crisis abated.[[99]](#footnote-99)

Do the shortages of the mid-380s support Harper’s statement that the fourth century showed spatially widespread famines of a kind unseen before? The case is not really strong, but the patchy evidence on harvest failures and food shortages (and the different coverage and nature of the sources that was mentioned above) does not allow firm denial either. We simply cannot measure famines and food shortages over the centuries. The more significant element in these events is that Rome could not count anymore on the resources of the entire empire, as it had in the early empire. Harvests failures had occurred in all periods, in the early empire just as well as in the third and fourth centuries (though possibly now more often). What had significantly changed, though, was the status of Rome. Since Constantine had founded Constantinople, it was not the sole capital of the empire anymore, and Egypt’s grain was destined to Constantinople. Rome now depended largely on Africa, Sicily and Sardinia, as it had 400 years earlier, and on imperial favor. What Symmachus’ letters reveal is that Rome’s city prefect had insufficient influence to determine the destination of the imperial grain fleets. In that sense Rome had come to resemble Ephesus: a city that was first in line, once imperial demands had been fulfilled. In short, what these events primarily show is not that environmental conditions caused the empire to totter, but that political power had shifted.

Let us return to the implied causality in the observation that the Empire was politically stable when the Nile floods behaved according to expectations, while the period of increased frequency of failed Nile floods coincided with political instability, civil war and military failure. Is it actually likely that the fate of the empire depended on Egypt’s grain? The largest part of Rome’s troops were stationed in the north of Britain and along the Rhine and Danube, beyond reach of Egypt’s grain. Furthermore, if the detrimental impact of insufficient Nile floods would have had a devastating impact on the imperial control of grain, one would have expected the resulting political unrest and military strife to concentrate on Egypt, the major source of grain. However, Egypt does not play a major role in the civil wars of the third or fourth century, and neither does Africa, the second most important supplier of grain to the Roman authorities. In fact, the majority of civil wars were fought between the military forces of Britain, the Rhine-provinces and those along the Danube, which were almost all beyond the reach of Egyptian grain. The dominant army, which generally succeeded in putting its candidates on the throne, consisted of the legions on the Danube, not those stationed in the East, who seem to have profited most from Egypt’s supplies. Should we assume that this balance of power was due to Egypt’s instability as bread basket? Now, that would be interesting, as it would mean that those armies who relied on the grain fields of north-western and central Europe actually fared better than those relying on Africa and Egypt, and that at a time when climate change is supposed to explain the downfall of the West and the survival of the East.

Equally significant is the increase of wine production in Egypt in the third century. To quote Irene De Soto’s recent study of the ceramic evidence of wine production and wine trade: “the assemblages found throughout Egyptian territory point to an increase in consumption of Egyptian wine during the third century CE, paired with a substantial decrease of imported wine, as compared to the first two centuries of Roman Imperial rule. Around the middle of the fourth century, however, products from Palestine and Cilicia start to appear or reappear in larger quantities, although with the exception of Tell el-Makhzan, they rarely make up the majority.”[[100]](#footnote-100) If indeed a weakening of the grain production had caused serious stress on the grain supply in the third century and problems for the imperial authorities, why would we see a shift towards greater wine production during that century, the more so as other regions are supposed to suffer from frequent harvest failures too?

To conclude: it is possible to construe a chain of causality in the events of the third and fourth century that agrees with the hypothesis that climatic change causing more frequent harvest failures in Egypt was linked to political instability and military decline. Is there any proof for this theory? No. One has to admit, though, that the limited range and patchiness of data would make that difficult. Is it possible to clearly disprove this construct of fact and postulations? No, it is not, as in the absence of detailed figures on harvests, grain prices, flows of grain etcetera one cannot rule out that harvest failure did play a role. However, the theory does seem to be based on some unlikely assumptions and causal links that nothing in the existing evidence compels us to make, apart from the chronological coincidence between an increasing volatility of the Nile floods and the peak of political unrest in the Roman Empire. Hence, there is no reason to assume that the political and military unrest of the third century was related to increasing pressure on agricultural resources that had dried up as a result of climatic factors.

**Zooming in on climate change and society**

Generalizations on the level of the western and eastern half of the Roman Empire are not useful. Future research should zoom much closer in on high-resolution data on local changes in settlement patterns and exploitation and local proxies of climate change in a wide variety of landscapes and economic contexts in order to clarify this issue. We have to zoom in on particular regions in the first millennium AD to establish which changes in landscape, agriculture and settlement pattern we do see that can either be linked to changing trends in temperature and precipitation, or to changes in the economic and political context, or, indeed, to a combination of both. For now, we will have to limit ourselves to a few case-studies, based on recent research.

*Levant and Syria*

According to one recent study, proxies indicate a period of generally wetter and probably warmer conditions in the eastern provinces during the early imperial period up to AD 300, followed by a decline in humidity that reached its nadir between AD 350 and 470. The relatively drier period of the fourth and fifth centuries was followed by a wetter phase that peaked in the sixth and seventh centuries. At the same time, recent archaeological studies point to village growth, persistence of farmsteads and the emergence of large settlements in the late antique period. Regarding the Syrian Limestone Massif, it is concluded “A substantial demographic growth in ca. AD 330-550 (culminating in AD 450-530) was connected with an increase in the size of settlements and individual farms. Stagnation set in around AD 550-610.”[[101]](#footnote-101) In other words, demographic and economic growth do not correspond with trends in precipitation. Izdebski et al. point to agricultural activity in the Negev in late antiquity, which today is too dry for rain-fed agriculture, but they also observe that the expansion of settlement occurred before humidity increased, while it lasted after drier conditions set in (i.e. after about AD 670). Hence, the authors conclude that political security and economic incentives that stimulated investments in irrigation were vital for the development of agriculture in this region.[[102]](#footnote-102)

*Anatolia*

In the intensively studied town of Sagalassos (SW Turkey) and its hinterland, we see demographic growth until the fifth and sixth century, coupled with a shift from individual farmsteads to villages. Paleobotanical analysis shows a lessening of the early imperial concentration on naked wheat and olives, which were replaced with a greater diversity of cereals and legumes in late antiquity. Pulses, millet and barley may reflect a greater desire to avoid risk at the cost of profit opportunities. Olives became much less visible. This process may be partly due to the climate, as the environment shows signs of greater humidity from the later third century until the middle of the seventh century, but Jeroen Poblome relates the shift in cropping strategies also to changes in the wider economic context.[[103]](#footnote-103) Increasing pressure on the productive landscape seems denied by the continued predominance of cattle, even though sheep, goats and pigs are also present at many sites. Since cattle are more demanding in their fodder requirements than sheep, goats or pigs, their lasting presence in the hinterland of Sagalassos, with a peak in the late Roman period, speaks against increasing constraints either by the growing population or by worsening climatic conditions.[[104]](#footnote-104) In sum, the hinterland of Sagalassos transformed from the beginning of the imperial period until the early Byzantine period, but this seems more due to societal processes than to natural forces.

The study by Izdebski et al. shows that general climatic trends in Anatolia were very similar to those in the Levant and Syria. Anatolia saw expansion of rural settlement combined with agricultural intensification and specialization during Late Antiquity. The authors link the drier conditions of about 350-470 to a greater frequency of subsistence crises in our written sources (however, see our critical remarks above), but the decline of precipitation is also said not to have brought about major societal change.[[105]](#footnote-105) Decline in the form of land abandonment and settlement collapse came after AD 640,[[106]](#footnote-106) but this cannot be linked to a reversal in climatic conditions at the time and is therefore ascribed to the disastrous Roman-Persian wars of the early seventh century, followed by the Arab conquest. The study of Izdebski et al. ends with the concluding remark that “climatic change thus played an important role in the major upheavals that brought about the end of Antiquity in the Eastern Mediterranean, but it was one factor among others, not a mono-causal explanation for societal transformation.”[[107]](#footnote-107) Recently, John Haldon acknowledges the impact of climate on landscape and society of Byzantine Anatolia, but makes two observations: first, paleoclimatic data show a great local variability in climate change patterns; secondly, the influence of climate change differed widely, depending on local environmental and societal conditions.[[108]](#footnote-108)

*Peloponnese*

A recent study on the Peloponnese concludes that “there can be no general association made between societal expansion phases and periods of advantageous climate”. “Local socio-political processes were probably always the key drivers behind the diverse strategies that human societies took in times of changing climate.”[[109]](#footnote-109) The researchers observe a clear difference in the settlement trajectories between the eastern and western Peloponnese during the Hellenistic and Roman period (300 BC – AD 300), which are not ascribed to significant climatic variations, but to differences in the socio-political structures. The northeast of the Peloponnese shows a continued high number of sites even within the drier period indicated by local paleoclimatic proxies. The years between ca. AD 160 and 350 appear relatively wet, followed by several decades of drier conditions in the eastern Peloponnese. The western coast appears to have been wetter between AD 550 and 800, while the inland and east coast were drier in this period. The driest period in the east was around AD 650-700. However, the increased aridity during the Late Roman and early Byzantine period “does not appear to have impeded the expanding cereal cultivation and rural settlement inland and in the eastern Peloponnese”.[[110]](#footnote-110) The final collapse of the late Roman economy occurred after AD 600, but may be related not only to a peak in aridity, but also to the collapse of political institutions at the same time.[[111]](#footnote-111) One might want to link the institutional collapse to the climate, but ruinous warfare in the Balkans had a much more direct impact.[[112]](#footnote-112)

*Epirus*

In contrast to the above case-studies, a study of a coastal region in modern Albania concludes that “phases of maximum settlement intensity in Butrint coincide with warmer and/or stable climate periods (0-800 AD and MCA [=Medieval Climate Anomaly], respectively), indicating a long-term influence of climatic conditions on human activities.”[[113]](#footnote-113) The evidence of the Lake Butrint points to a long period of relative stability between about the start of the first century AD to about AD 900. However, within this period of stability, two distinct phases are identified: a generally warmer and humid period up to about AD 400, followed by an increase of moisture until about AD 900.[[114]](#footnote-114) However, the same study also notes lower temperatures from the first to eighth centuries than before or after.[[115]](#footnote-115) During this entire period, the region experienced a phase of high occupation, with a peak between ca. AD 400 and 550. Sudden decline in habitation and exploitation in the seventh century is not linked to climate change, but to the wars against and conquest by the Slavs, as in the Peloponnese, as we just saw.

*Sicily*

A humid period from c. AD 450-750 was followed by a sudden period of aridity[[116]](#footnote-116), which is linked to a phase of socio-economic and agricultural decline that lasted until about AD 1000.[[117]](#footnote-117) More generally, isotopes indicate on the one hand that the climate from about AD 0-1100 was on average wetter than afterwards; on the other hand that climate was rather stable during this entire period, with limited changes in humidity. In other words, the humid period of 450-750 was only moderately wetter than the centuries before or after.[[118]](#footnote-118) It coincides with a period of intensive land use and high settlement density in both inland and coastal regions, which are due to societal factors causing the economic intensification of Sicily during the Later Roman Empire: first, as we have seen, Rome lost access to Egyptian grain with the foundation of Constantinople in the 320s; second, the Vandal conquest of Africa in the 430s ended Roman control of this major supplier. While the city of Rome declined in the Byzantine-Gothic Wars of the 6th century, Sicily became a supplier of grain towards the Byzantine Empire, under whose authority it now fell.[[119]](#footnote-119) Hence, favorable climatic conditions coincided with political and economic developments that increased the outside demand for crops.

On the other hand, economic decline in the eighth century coincides with the arrival of drier climatic conditions, and the authors suggest that this represents a “significant temporal correlation”.[[120]](#footnote-120) However, they also note that this decline “is the only case we were able to identify in which climatic fluctuations contributed to a major socio-economic change. During the Middle Ages, the drier conditions did not impede the agricultural recovery of the Norman period”.[[121]](#footnote-121) Hence, the decline of the 8th century should not be ascribed solely to a decrease in precipitation, but rather to the combination of less favorable climatic conditions and the absence of incentives to overcome these conditions, unlike the Norman period. The increasingly frequent attacks of Arabs offer sufficient explanation for the reluctance to invest capital in irrigation systems. In short, the climatic and human history of late ancient and early medieval Sicily strengthens the hypothesis that climate change rarely in itself determined socio-economic developments.

**Resilience in East and West**

Although the impact of adverse trends in temperature and precipitation on agricultural production is neither straightforward nor uniform, it is not impossible that changes in the pattern of extreme weather raised the frequency of bad harvests of cereal crops in those regions that were susceptible to these changes. While I reject the image of centuries of good or bad harvests that is invoked by the misleading terminology in some of the climate change-literature, variations in the volatility of harvests are entirely likely. However, harvest shocks constitute only one element in the food supply, another crucial element being the extent to which carry-over and distribution in the form of market and non-market mechanisms are able to alleviate the impact of annual harvest fluctuations. In other words, not only climate change is important, but also the capacity for resilience of a society to deal with its adverse effects. The hypothesis proposed here is that the economic decline in the West from the third century AD onwards, in contrast to the continued prosperity in the East, was due to the weakening of those commercial and socio-political mechanisms that at the zenith of the empire in the West had succeeded in alleviating local harvest shocks. This is not to say that public and private mechanisms had previously always succeeded in preventing food shortages, as disastrous famines did occur in East and West at all times, though not in the political centers like Rome itself, which could count on imperial intervention until the very end of the western empire.[[122]](#footnote-122) The consequences of the weakening of these societal mechanisms went beyond the food supply, as it triggered the spiraling down of the entire urban and rural economy. We will sketch this process in the following section, focusing particularly on Gaul, which in the early empire was one of the most prosperous regions in the West.

The configuration of economic determinants in the western provinces during the early empire favored economic growth and complexity. The towns and cities, but also the armies on the Rhine frontier, offered stable markets for a wide range of goods and services, stimulating market-oriented agricultural enterprises that generated large and relatively stable surpluses. The numerous villas produced foodstuffs and raw materials for the non-agricultural sectors, which were in turn stimulated by the presence of prosperous markets for raw materials and finished goods. The growth of the non-agricultural sectors allowed the productive employment of a larger share of available labor in the countryside, and all this was made possible by the increased market integration that was stimulated by Roman pacification and infrastructure and by the relative urban price stability underwritten by civic-minded ruling elites. We should not exaggerate the prosperity and stability of urban and rural society, nor underestimate the extent of social inequality that allowed a small segment of society to reap most of the rewards of economic growth, but this was a society in which numerous cash-crop farmers, shopkeepers and artisans in towns and *vici* deemed their small businesses sufficiently stable as to wager their households’ subsistence on them.[[123]](#footnote-123)

The state had a significant role in the distribution network that underpinned economic growth, as the Roman armies on the Rhine and upper Danube were supplied with large volumes of Mediterranean goods, including olive oil from Spain and wine from southern Gaul. The Roman legionary camps formed large concentrations of consumers with hard cash to spend. Most importantly, the Roman state organized the provisioning of basic goods up to the armies. Tchernia has shown that the supply chains that supplied the armies on the Rhine with olive oil were dominated by state needs and not commercial networks. Along the long supply lines there were branch lines leading to large coastal or riverside towns, but entire regions were not directly served and were only connected in regional markets.[[124]](#footnote-124) Nevertheless, the state supply had an important indirect effect on commercial channels. In the words of Tchernia, “the possibility of combining supplies ordered and issued by the army with those that the traders delivered for open sale reduced both transaction and transport costs, increased the number of purchasers, and gave a substantial fillip to commercial endeavours.”[[125]](#footnote-125) Ships and river boats bringing army provisions to the North did not go back empty, so even if the state-induced transportation was basically one-way, it stimulated also distribution the other way. Moreover, ships not only carried state-goods, but also commercial cargo, such as the fine pottery of La Graufesenque or other workshops, whose products during the early empire could be found all over the western Mediterranean.[[126]](#footnote-126) The traders and shippers involved in this network organized themselves in order to deal with the authorities and to reduce their transaction costs.[[127]](#footnote-127) The military supply-network thus not only stimulated market integration through its infrastructure and the movement of ships, but also through the connections and communication it provided. We may refer here to two *decuriones* (town councilors) from Gaul who in the second century AD honored their *amicus et sodalis* (friend and partner) for his contribution to the food supply of their home-town. The latter was a citizen from Carthago Nova (on the southeast coast of Spain) who was possibly involved in provisioning the Roman armies along the Rhine.[[128]](#footnote-128) In short, the merchants and shippers that were involved in the supply-chain between the Mediterranean on the one hand, and the army camps and cities on the frontiers on the other stimulated communication and trade throughout this wider region.[[129]](#footnote-129) Since information and communication are as important to market integration as harbor facilities, the state contributed to creating the circumstances needed to increase the economic performance in this part of the Roman world.

Warfare only became chronic within the western provinces in the mid-third century, but from the reign of Marcus Aurelius (AD 161-180) onwards, the military situation within the Roman Empire changed sufficiently to gradually and slowly impair the conditions of commerce and trade. The intensity of external war had changed, as Rome now regularly had to wage serious wars on several fronts at the same time, with civil war adding to the burden in the 190s and from the 230s onwards almost permanently. The first major change that we see, around the turn of the second and third century, is the rapid dwindling of the provisioning of Mediterranean supplies to the Rhine frontier. By 300 the provisioning had come to a complete halt.[[130]](#footnote-130) The causes for this development have to be sought at least partly in the changing ethnic composition of the legions stationed along the Rhine and *limes*, as the troops were increasingly recruited from the frontier zone rather than from the Mediterranean lands. Hence, dietary preferences of the troops had changed, and olive oil was probably being replaced with butter or lard, while wine now largely came from central Gaul. Not coincidentally, all attestations of *collegia* in the service of the annona in Seville end in the early third century.[[131]](#footnote-131) For Gaul it meant a shrinking of the state-supported supply network, which must have had a negative impact on the conditions of trade and communication in the region. We see this reflected in the third century in the much reduced distribution radius of the fine pottery produced in Gaul.[[132]](#footnote-132)

Around the turn of the second and third century we also see a decline in the activities that traditionally reflected and propagated the civic-mindedness of the urban elites. In the late first and second century the provincial towns and cities had witnessed an upsurge in the construction of public buildings and monuments that characterized the Roman city in the West, like fora, temples, theatres and bath-houses, partly paid by the public funds of the towns, partly by the munificence of the leading families. Benefactions and civic spending on the food supply, festivals and public buildings were part of their legitimation as ruling elite and a way to emphasize their social status. In the early empire, members of the ruling families, either as state officials or as private benefactors, regularly intervened in the urban food supply during shortages by making grain available at reduced (if still high) prices or by arranging for outside grain to be shipped in. At the end of the second century, however, the drive to finance civic projects came to a standstill, which is reflected in a slump in the public inscriptions that advertise the public role of the members of the ruling elites. Esmonde Cleary ascribes this development to a lessening of the need the leading families felt to confirm and legitimize their social and political status, which affected their inclination to invest money in public monuments.[[133]](#footnote-133) We see this development not only in Gaul, but also in Spain, where from the second half of the second century onwards, ruling families did not find it useful anymore to inscribe their functions and deeds in stone or to invest in public works in order to enhance their reputation.[[134]](#footnote-134) Hence, the attitude of the urban elites towards their civic responsibilities had significantly changed by the start of the third century. The church would eventually take over this role, but only in the fifth century the bishops would have sufficient resources to take up famine-relief in any meaningful way.

Both developments – the dwindling of the imperial supply network and of the civic mindedness of local elites – increased the vulnerability of the urban populace to price volatility. Economic circumstances therefore significantly worsened even before continuous and large-scale warfare reached the Roman West. The frontier wars and civil strife of the mid-third century catalyzed the downward spiraling of the economy. By the end of the third century it was undoubtedly much harder to alleviate the impact of a local harvest failure than 150 years earlier. Although we lack price data to confirm the hypothesis, we may be certain that price volatility increased disastrously in regions regularly affected by external and internal warfare. The risks increased particularly for those involved in the non-agricultural sectors, as in times of shortage they were confronted with both high food prices and a slump in the market for their own products. We see this reflected in the rural habitation pattern, as the *vici*, nucleated settlements of artisans and small-scale traders, which were omnipresent in the early empire, disappeared from the late Roman countryside.[[135]](#footnote-135) As towns shrank and vici disappeared, so did the markets for commercial agriculture.[[136]](#footnote-136) John Drinkwater suggested that it was in particular the violent suppression of the Gallic Empire by Aurelian and the following retribution that broke the Gallic spirit, ruined the land and destroyed the cities.[[137]](#footnote-137) Shrinking towns and cities in Gaul from the mid-third century onwards meant a decline in urban markets for goods and labor.[[138]](#footnote-138) As the wider economy shrank and employment opportunities in the non-agricultural sectors declined, proportionately more people worked the land. The earlier trend reversed and productive labor in urban and rural non-agricultural sectors were shifted again to higher levels of underemployment and lower levels of productivity on the land. Capital-intensive forms of direct exploitation became less attractive, while small-scale tenant households gradually started to play a greater role, relative to servile workforces, on the estates of large-landowners. Inevitable consequences of the structural shift in agriculture towards small-scale tenancy were lower levels and greater volatility of surplus production.[[139]](#footnote-139) Hence, the vanishing of urban markets went hand in hand with the decline in surplus production.[[140]](#footnote-140)

The increase in the frequency of food shortages that were the consequence of a weakening of societal responses to harvest failures, military requisitions and war-time devastations may be related to rising levels of mortality. A study by Kelly and Ó Gráda of medieval and early-modern England reveals the complexity of the demographic consequences of food shortages.[[141]](#footnote-141) They analyzed year-by-year data on food prices, indicating harvest failures, and deaths among tenants and lords, which show that even limited shortages caused a subsequent rise in mortality. Even during famines, most people died of disease, not of starvation. Interestingly, Kelly and Ó Gráda’s study reveals that deaths rose first among tenants and only after a time-lag among lords. In other words, harvest failures disrupted the lives of tenants, increasing their mobility and causing their increased exposure to virulent and endemic diseases. The higher echelons of society only died when the emerging local disease outbreaks also affected them. This pattern only changed in the early-modern period, when governmental policy on the one hand intervened in the workings of the grain market, on the other hand addressed the issue of the vagrant poor. Both measures stopped the pattern of localized harvest failures leading to upsurges of infectious diseases. The link between harvest failures and deaths stopped last in London, which Kelly and Ó Gráda explain by the weakness of social ties in the metropolis. A few points can be made from this study that are relevant to the Roman world. The food supply was indeed causally linked to mortality, but not in the form of catastrophic virgin-soil epidemics, but rather in the form of small peaks in what still may count as background mortality. The link between volatility of harvests and fluctuations in mortality was responsive to governmental control. In other words, a functioning government and social ties could make a difference. In England, institutional progress between the 14th and 17th century diminished the impact of harvest failures on mortality. In the Roman West, it may be postulated, the weakening of government and the dwindling of vertical support mechanisms over the course of the third and fourth century caused the reverse. The lack of quantitative data means that we will never be able to prove the point, but if correct, population decline may at least partly be attributed to increasingly frequent upsurges of locally endemic diseases.

In contrast to the West, which showed decline on all counts, high levels of population and urbanization, market-oriented farms, large-scale distribution, and the mass-consumption of the products of artisans continued to characterize the economy of the East until the sixth century.[[142]](#footnote-142) Since Hellenistic times, the East and Africa boasted cities exceeding 100,000 inhabitants, only surpassed by late-Republican Rome on the basis of its vastly greater political power. The western provinces never counted a city of such a size. Economic performance in the West was less based on mega-cities and more directly connected to the state, in particular the army and the apparatus supporting the army, while the East had large cities that continued to function as catalysts fueling the economic chain-reaction of market and production.[[143]](#footnote-143) The continued prosperity of the late-Roman villages in the Syrian limestone Massif, for example, was partly based on the production of olive-oil for outside markets. The distribution of the amphorae shows that the markets encompassed the entire East, including the armies on the eastern frontier.[[144]](#footnote-144) Until the sixth century, most regions in the East do not show decline regarding the range of goods produced, the geographical scale of its distribution, or the extent to which it penetrated rural and poorer segments of society.[[145]](#footnote-145) Despite political instability and the increasing burden of the armies, the mega-cities kept the East and Africa from spiraling downwards. They not only ensured a continuing market for artisans and commercial farmers in the fifth and sixth centuries, but state-induced distribution networks maintained the relative price stability, infrastructure and flow of information and communication that were necessary for the wider economy to prosper.

**Conclusions**

There is no denying that the climate changed significantly in long-term processes over time, but the impact of such changes in the patterns of temperature and precipitation is as diverse as human societies were. Since the emergence of complex societies, their ability to deal with changing circumstances has often been more important than the kind of climate change that the later Holocene has witnessed, at least until recently. However, modern studies stressing environmental forces generally present an image of societies forever on the brink of collapse, only needing a little nudge to go over the edge. The Roman world was not severely constrained by Malthusian limitations or subjected to hurtful Malthusian pressure. For a few centuries, economic growth outpaced demographic growth. Even if per capita growth was not spread evenly among Rome’s subjects, significant segments of society profited from higher living standards and wider consumption choices. There is no sign that the Roman world hit a Malthusian ceiling, resulting in declining living standards, though average living standards certainly fell in parts of the West from the third century onwards. The efflorescence was much more short-lived in the West than in Africa or the East.

It is an oversimplification to argue that climate change lowered the carrying capacity of the Roman world, causing a breakdown of the political institutions and economic structures of the Roman state. Paleoclimatic indicators show changing trends in precipitation and temperature that affected agriculture, but patterns are less clear and changes less catastrophic than some recent publications claim. Other, more regionally focused studies show that changes in society do not always conform to general assumptions regarding the impact of climate, which confirms that human society was not the passive subject of climatic conditions. Beneficial climatic conditions generally allowed expansion of exploitation and habitation, but the reverse was far from inevitable. Societal circumstances determined whether carry over, distribution, drainage, irrigation or changes in cropping strategies overcame adverse natural conditions.

The political and economic circumstances that triggered growth in the West turned out to be fragile, depending on a particular configuration of the functioning of the Roman state and the mentality of the ruling elite - a mentality that in the West rapidly changed when the civic-mindedness of the classical polis became an anachronism. There is no reason to assume that the political and military unrest of the third century was related to increasing pressure on limited resources. Climate change may have caused an increase in the frequency of harvest failures in the West, but far more damaging was the declining ability of society to alleviate the impact of harvest shocks on the food supply, the wider effects of which triggered a fall in population figures and the spiraling down of the economy of the West.

1. J.L. Brooke, *Climate change and the course of global history*, Cambridge 2014, pp. 1-2. I would like to thank xxx, xxx and xxx for their valuable comments and suggestions. [↑](#footnote-ref-1)
2. A. Demandt, *Der Fall Roms. Die Auflösung des römischen Reiches im Urteil der Nachwelt*, Munich 1984. Reproduced in: B. Ward-Perkins, *The fall of Rome and the end of civilization*, Oxford 2005, 32. [↑](#footnote-ref-2)
3. Otto Seeck saw internal developments as mainly responsible for racial degeneration, while many contemporaries blamed it on racial mixing in Roman society. [↑](#footnote-ref-3)
4. M. McCormick, U. Büntgen, M.A. Cane et al., ‘Climate change during and after the Roman Empire. Reconstructing the past from scientific and historical evidence’, *Journal of Interdisciplinary History* 43 (2012) 169-220. Apart from the publications mentioned, also U. Büntgen et al., ‘2500 Years of European Climate Variability and Human Susceptibility’, *Science Magazine* 331 (2011) 578-582. S. Hin, *The demography of Roman Italy. Population dynamics in an ancient conquest society, 201 BCE-14 CE*, Cambridge 2013, ch. 3 ‘Climate and climate change’ deals primarily with the beneficial aspect of the emerging Roman Climatic Optimum on demographic and economic growth. A.J. McMichael, *Climate change and the health of nations. Famines, fevers, and the fate of populations*, Oxford 2017 offers a global environmentally deterministic account, but his treatment of Roman history is seriously marred by factual errors. [↑](#footnote-ref-4)
5. Kyle Harper, *The fate of Rome. Climate, disease and the end of an empire*, Princeton 2017, quotes from pp 4-5, 19. [↑](#footnote-ref-5)
6. Ward-Perkins 2005, 134, wrote: “Acts of God tend to occur in all periods of history, but their effects are generally long-lasting only when an economy is already in trouble.” The difference is of course that Ward-Perkins is not dealing with long-term adverse climate change but with individual crises, even though publications on climate change in the first millennium AD were being published when he wrote his book. C. Wickham, *Framing the early Middle Ages. Europe and the Mediterranean, 400-800*, Cambridge 2005, 13 warns us to resist the lure of catastrophes as causes of historical processes, though they might speed up trends that are determined by more fundamental causes. Recently, P. Slavin, ‘Climate and famines. A historical reassessment’, *WIREs Climate Change* 7 (2016) 433-447, 439: “To blame climate as the universal trigger of cataclysm means to reduce a historical argument to the oversimplified level of environmental determinism, which does not account for other, no less decisive factors.” Cf. T.P. Newfield and I. Labuhn, ‘Realizing consilience in studies of pre-instrumental climate and pre-laboratory disease’, *Journal of Interdisciplinary History* 48 (2017) 211-240, 214-215: “Since resilience is difficult to perceive when written sources are few, the natural world tends to predominate in dark ages.” See also J. Haldon, *The empire that would not die. The Paradox of Eastern Roman Survival, 640–740*, Cambridge MA 2016, 222-224. [↑](#footnote-ref-6)
7. Compare the study of the Byzantine Empire by E. Xoplaki et al., ‘The Medieval Climate Anomaly and Byzantium. A review of the evidence on climatic fluctuations, economic performance and societal change’, *Quaternary Science Reviews* 136 (2016) 229-252, 246-249: dry and cool phases did not hamper population and economy to reach a peak in the mid-twelfth century, when the socio-political system functioned well, but contributed to the decline from about AD 1200, when the socio-political system weakened. “The impact of climate change amplified or exacerbated a range of inter-related pressures that placed stress on various key elements of Byzantine society and economy” (p. 249). T. Newfield and I. Labuhn, ‘Towards a messy history of crisis and climate in Carolingian Europe’, 2016, [www.historicalclimatology.com](http://www.historicalclimatology.com) note that “moments and mechanisms of early medieval resilience” are missing from the debate. F.L. Cheyette, ‘The disappearance of the ancient landscape and the climatic anomaly of the early Middle Ages. A question to be pursued’, *Early Medieval Europe* 16 (2008) 127-165, 164 speaks in terms of climate change reinforcing economic decline in the West, thereby creating a ‘feed-back-loop’. [↑](#footnote-ref-7)
8. There is no point in referring to all relevant publications here. An excellent introduction is A. Zuiderhoek, *The ancient city*, Cambridge 2017. See also Ward-Perkins 2005, ch. 7. On late Roman prosperity in Africa and the East, see Wickham 2005, in particular his chapters on cities and systems of exchange. [↑](#footnote-ref-8)
9. Cheyette 2008, 135-138. [↑](#footnote-ref-9)
10. See the overview of archaeological evidence in S. Esmonde Cleary, *The Roman West, AD 200-500. An archaeological study*, Cambridge 2013, 66-73 (North), 107-112 (South), 201-206 (Trier). [↑](#footnote-ref-10)
11. This is not the place to discuss this matter. See the debates in A. Bowman and A. Wilson (eds.), *Quantifying the Roman economy. Methods and problems*, Oxford 2009; F. De Callataÿ , F. (ed.), *Quantifying the Greco-Roman economy and beyond*, Bari 2014. [↑](#footnote-ref-11)
12. For a criticism of too simplistic interpretations of the number of wrecks, A. Tchernia, *The Romans and trade*, Oxford 2016, 117-121. [↑](#footnote-ref-12)
13. W. Jongman, ‘Gibbon was right: the decline and fall of the Roman empire’, in: O. Hekster, G. de Kleijn and D. Slootjes (eds.), *Crises and the Roman Empire*, Leiden 2007,183-99. Criticized by P. Halstead, ‘The Contribution of Zooarchaeology’, in: P. Erdkamp and C. Holleran (eds.), *Handbook to Diet and Nutrition in the Roman World*, London 2019, . This is not to deny, though, that much could be done by focussing on shifting patterns in the age of animals, as this might indicate a shift to meat consumption as primary goal instead of secondary products such as labour, wool or hides. [↑](#footnote-ref-13)
14. Wickham 2005, 700; E. Mayer, *The ancient middle classes. Urban life and aesthetics in the Roman Empire, 100 BCE – 250 CE*, Cambridge, MA 2012, in particular ch. 3. [↑](#footnote-ref-14)
15. McCormick et al. 2012, 169-220; S.W. Manning, ‘The Roman world and climate. Context, relevance of climate change, and some issues’, in: W.V. Harris (ed.), *The ancient Mediterranean environment between science and history*, Leiden 2013, 103-170; Brooke 2014. [↑](#footnote-ref-15)
16. McCormick et al. 2012, 203. [↑](#footnote-ref-16)
17. Manning 2013, 169-170. [↑](#footnote-ref-17)
18. Brooke 2014, 343, 346. Repeated in J.L. Brooke, ‘Malthus and the North Atlantic Oscillation. A reply to Kyle Harper’, *Journal of Interdisciplinary History* 46 (2016) 563-578, 567-569, where Brooke rejects Harper’s claim that the decline of the 2nd century AD was related to adverse climate change. [↑](#footnote-ref-18)
19. Brooke 2014, 325-326. Brooke (p. 315) also suggests that the colder climate undermined the health of the population of the Roman Empire, as it forced people to live indoors, in smoke-filled dwellings, crowded and with their animals. I do not see how this statement is to be combined with the argument that the inhabitants of northern Europe were healthier and taller than the inhabitants of the Roman world. [↑](#footnote-ref-19)
20. Brooke 2014, 346. Similar, McCormick et al. 2012, 190. [↑](#footnote-ref-20)
21. Harper 2017, 131. [↑](#footnote-ref-21)
22. Ibidem, 168-169. [↑](#footnote-ref-22)
23. Ibidem, 253-254. [↑](#footnote-ref-23)
24. A. Izdebski et al., ‘Realising consilience. How better communication between archaeologists, historians and natural scientists can transform the study of past climate change in the Mediterranean’, *Quaternary Science Reviews* 136 (2016) 5-22, 12: “The fact that two events happen at the same time should not be taken uncritically as solid evidence of causation.” [↑](#footnote-ref-24)
25. Thus, B.L. Drake, ‘The influence of climatic change on the Late Bronze Age Collapse and the Greek Dark Ages’, *Journal of Archaeological Science* 39 (2012) 1862-1870. But see criticism in Manning 2013, 115, n. 12. E. Weiberg et al., ‘The socio-environmental history of the Peloponnese during the Holocene. Towards an integrated understanding of the past’, *Quaternary Science Reviews* 136 (2016) 40-65, 47 point out that drier conditions prevailed both during the rise of Mycenaean palace economies and their demise. [↑](#footnote-ref-25)
26. Brooke 2014, 323. [↑](#footnote-ref-26)
27. A criticism also made by K. Harper, ‘Civilization, climate, and Malthus. The rough course of global history’, Journal of Interdisciplinary History 45 (2015b), 549-566, 557: “… working without any explicit model of human social life”. [↑](#footnote-ref-27)
28. Brooke 2014, 357. [↑](#footnote-ref-28)
29. Ibidem, 327. [↑](#footnote-ref-29)
30. Ibidem, 325. [↑](#footnote-ref-30)
31. Izdebski et al. 2016, 12: “there is a risk of subjectivity involved in the data collection and choice”. [↑](#footnote-ref-31)
32. Drake 2012, 1868: “The recovery of populations and the re-urbanization of Greece may have been related to innovations in agriculture”. Cf. Manning 2013, 112-115; Brooke 2014, 324. [↑](#footnote-ref-32)
33. For an introduction into the methodology: R.S. Bradley, *Paleoclimatology. Reconstructing Climates of the Quaternary*, 3rd edition, Amsterdam 2015. A critical overview also in Manning 2013. B.B. McShane and A.J. Wyner, ‘A statistical analysis of multiple temperature proxies. Are reconstructions of surface temperatures over the last 1000 years reliable?’, *Annals of Applied Statistics* 5 (2011) 5-44 offer a statistical analysis of a wide spectrum of proxy-data in the second millennium AD and of their correlation with measured temperatures over the past 150 years. Their conclusion confirms the global warming trend in the past decades, but they also note “that natural proxies are severely limited in their ability to predict average temperature and temperature gradients” (p. 8). Taken together with the high regional variability of precipitation (on which below), this is at least a valuable counterbalance to the overly confident reconstructions of past climate change in such studies as Brooke’s and Harper’s, the more so as the proxies before AD 1000 offer certainly no higher resolution or accuracy than the one’s after AD 1000. It is unfortunate that in a field that requires multidisciplinary cooperation, the highly politicized debates on climate change complicate the assessment of highly complex statistical arguments for scholars outside this particular field of expertise. [↑](#footnote-ref-33)
34. A. Gogou et al., ‘Climate variability and socio-environmental changes in the northern Aegean (NE Mediterranean) during the last 1500 years’, *Quaternary Science Reviews* 136 (2016) 209-228, 219: “dating uncertainties restrict in many cases the comparison between different archives (e.g. marine, lake and stalagmite records)”. [↑](#footnote-ref-34)
35. Thus, Weiberg et al. 2016, 51: “Due to the current lack of dating precision for both the archaeological and climate data, it is impossible to evaluate the potential societal impact of these drier conditions”, referring to the Peloponnese around AD 600. [↑](#footnote-ref-35)
36. Hin 2013, 69: “Severe weather was a topos.” [↑](#footnote-ref-36)
37. Harper 2017, 170. [↑](#footnote-ref-37)
38. Cf. J. Haldon et al., ‘The climate and environment of Byzantine Anatolia. Integrating science, history, and archaeology’, *Journal of Interdisciplinary History* 45 (2014) 113-161, 126-127, who point out that there is a close match between proxy data on precipitation and literary mention of drought in Anatolia between AD 300 and 870. [↑](#footnote-ref-38)
39. Brooke 2014, 277, 291. Cf. McCormick et al. 2012, 203. [↑](#footnote-ref-39)
40. Flavius Josephus, *Jewish Antiquities* 15.299ff, 20.51. [↑](#footnote-ref-40)
41. M. Kelly and C. ÓGráda, ‘The Waning of the Little Ice Age: Climate Change in Early Modern Europe’, *Journal of Interdisciplinary History* 44 (2014a) 301-325. Quote from p. 308. Also M. Kelly and C. Ó Gráda, ‘Debating the Little Ice Age’, *Journal of Interdisciplinary History* 45 (2014b) 57-68, 58-60. [↑](#footnote-ref-41)
42. Harper 2017, 55. [↑](#footnote-ref-42)
43. Emphasized regarding temperature by J. Luterbacher et al., ‘European summer temperatures since Roman times’, *Environmental Research Letters* 11 (2016) 024001, 10. [↑](#footnote-ref-43)
44. Manning 2013, 107; Harper 2017, 42, 255; Newfield and Labuhn 2017, 227. [↑](#footnote-ref-44)
45. Both the low resolution of data and the fuzziness of climatic periods contribute to the fact that Brooke, for example, has different beginning and end points for the same climatic period. The pre-classical climatic ‘low’ is said to last from 1300-700 BC, but also from 1200-600 BC or 1600-800 BC. The beginning of the Roman Optimum (Brooke calls it the Classical Optimum) is difficult to pin down (somewhere around 300 BC), but this is even more the case with its end, which is variously dated by Brooke somewhere between the 3rd and 6th centuries AD. Kelly and Ó Gráda 2014(a), 308-309 make the same point regarding the early-modern LIA. See S. White, ‘The real Little Ice Age’, *Journal of Interdisciplinary History* 44 (2014) 327-352, 345-351 for a response, and Kelly and Ó Gráda (2014b) 62. [↑](#footnote-ref-45)
46. Harper 2017, 44. Cf. Manning 2013, 159-161; Haldon et al. 2014, 121. [↑](#footnote-ref-46)
47. Regarding the so-called Dust Veil of 536 and the cold decade from AD 536-545, see Newfield and Labuhn 2017, 217-218. [↑](#footnote-ref-47)
48. F. Ludlow and J.G. Manning, ‘Revolts under the Ptolemies. A Paleoclimatological Perspective’, in: J.J. Collins and J.G. Manning (eds.), *Revolt and Resistance in the Ancient Classical World and the Near East. In the Crucible of Empire*, Leiden 2016, 154-171. [↑](#footnote-ref-48)
49. Luterbacher 2016, 8. [↑](#footnote-ref-49)
50. See also Cheyette 2008, 156 on this issue. [↑](#footnote-ref-50)
51. Manning 2013, 153-154: the Roman period from the 3rd century BC to the 5th century AD “appears as a relative sustained era of stability, and can be contrasted with the scale of changes evident in the 2nd millennium AD during the MCA or the subsequent LIA”. Cf. McCormick et al. 2012, 174. L. Sadori et al., ‘Climate, environment and society in southern Italy during the last 2000 years. A review of the environmental, historical and archaeological evidence’, *Quaternary Science Reviews* 136 (2016) 173-188, 177: “From 0 AD to ca. 1100 AD […] the climate was rather stable”. More pronounced changes occurred from AD 1100 onwards. [↑](#footnote-ref-51)
52. Cf. White 2014, 328 on the early-modern LIA: “This cooling stands out as undoubtedly the most pronounced global climate anomaly of the past 8,000 years.” Compare this with Harper’s designation of the early medieval LIA as a ‘biological catastrophe’. Early modern European societies showed both demographic and economic growth, not because the early LIA did not exist, but because their political, social and economic institutions offered resilience to adverse climate change. [↑](#footnote-ref-52)
53. Hin 2013, 66. [↑](#footnote-ref-53)
54. For example, in Macedonia, the cultivation of temperature-sensitive crops like the olive, grape and walnut expanded in warmer periods. Gogou et al. 2016, 221. [↑](#footnote-ref-54)
55. Paolo Malanima in A. Kander, P. Malanima and P. Warde, *Power to the people. Energy in Europe over the last five centuries*, Princeton 2013, 72-73. [↑](#footnote-ref-55)
56. Harper 2017, 52. Similar, Hin 2013, 86--90: “During warming periods, population has tended to grow; during cooling periods, it has tended to stagnate or decline” (p. 89). The figures are derived from E. Lo Cascio and P. Malanima, ‘Cycles and stability. Italian population before the demographic transition (225 BC – AD 1900)’, *Rivista di Storia Economica* 21 (2005) 5-40, 27. [↑](#footnote-ref-56)
57. Brooke 2016, 565. [↑](#footnote-ref-57)
58. 15-20 million is presented by W. Jongman, ‘The early Roman Empire: consumption’, in: W. Scheidel, I. Morris and R. Saller (eds.), *The Cambridge Economic History of the Greco-Roman world*, Cambridge 2007, 592-618, 6-5 as a theoretical figure. “What actually happened is, of course, a different matter”, he rightly adds. Hin 2013, 25-26 estimates 10 million people as the carrying capacity of Italy, N. Morley, *Metropolis and hinterland. The city of Rome and the Italian economy, 200 BC – AD 200*, Cambridge 1996, 49: 7.5 million. The wide range of estimates reveals the limited usefulness of the exercise. [↑](#footnote-ref-58)
59. “Direct dependence on the natural world in Roman times” does not mean that society or the economy are only or even primarily determined by natural forces . Cf. Hin 2013, 91. [↑](#footnote-ref-59)
60. J. de Vries (*Journal of Interdisciplinary History* 44 (2014) 369-377, 375) expresses a similar criticism of Geoffrey Parker’s *Global crisis. War, climate change and catastrophe in the seventeenth century*, New Haven 2013 in his review of the book: “This approach reduces the economy to little more than a direct physical relationship between weather and harvest results, but seventeenth-century economies in most of Eurasia were not so simple. Technology, markets, institutions could, and did, buffer the effects of climate on food production and distribution.” Cf. A.M. Rosen, *Civilizing climate. Social response to climate change in the ancient Near East*, Lanham 2007,15, who points out that climatic amelioration does not automatically lead to prosperity and population growth. If it does, there are always underlying cultural influences. [↑](#footnote-ref-60)
61. Cf. Gogou et al. 2016, 221-222, who suggest that the cooling of Macedonia in the late 11th century did not lead to any significant societal change, because the region was loosely populated and dominated by pastoral activities. [↑](#footnote-ref-61)
62. Hin 2013, 86, referring to tree ring width, states: “Crop growth in Italy would have been facilitated by the fading of the preceding cold spell and the warming of the local climate during the republican period.” However, dendrological data for the Mediterranean peninsulas are sparse, so that paleoclimatic reconstructions are usually based on central European data. Conclusions regarding plant growth cannot be extrapolated from central Europe to Italy. [↑](#footnote-ref-62)
63. Heinrich (forthcoming a). If a change in the circumstances the farmer is faced with is more considerable, shifting to another crop, for instance a different subspecies of wheat better suited to those circumstances, is also an option (Heinrich, 2017), In the longer term, genetic variation in ancient wheat populations would have allowed for adaptation through natural selection, the progeny of specimens best suited to new conditions becoming dominant, ultimately giving rise to better adapted cultivars or landraces. This adaptability is perhaps best illustrated by the observation that (different cultivars/landraces of) the wheat subspecies emmer wheat (*Triticum turgidum* ssp. *dicoccon*) were dominant/of great importance from the Neolithic through the Iron Age in Egypt, Italy and Britain – the latter case requiring what was originally a winter crop becoming a summer crop – see Heinrich forthcoming a for a discussion. [↑](#footnote-ref-63)
64. Malanima 2013, 40-41. It is clear that in relatively cold regions, such as Holland and England, summer temperature did influence harvests. Kelly and Ó Gráda 2014(a), 305 point to studies that show that a rise in summer temperature of 1 oC reduced wheat prices by 5 percent. [↑](#footnote-ref-64)
65. But even in temperate zones the relationship between light and yields is more complex and less straightforward than apparent in Malanima’s account. [↑](#footnote-ref-65)
66. Izdebski 2016, 7; Xoplaki 2016, 247. Likewise for the Levant, L.A. Maher, E.B. Banning and M. Chazan, ‘Oasis or Mirage? Assessing the Role of Abrupt Climate Change in the Prehistory of the Southern Levant’, *Cambridge Archaeological Journal* 21 (2011) 1-29, 20. [↑](#footnote-ref-66)
67. Izdebski et al. 2016, 7. Also J.M. Marston, *Agricultural sustainability and environmental change at ancient Gordion*, Philadelphia 2017, 49, “The relationship between climate-influenced climate change, human behavior and anthropogenic landscape change is complex and reciprocal, as well as variable over even short spans of time and space, which add additional complications to attempts at regional paleoenvironmental synthesis.” [↑](#footnote-ref-67)
68. Esmonde Cleary 2013, 266. [↑](#footnote-ref-68)
69. For an example in southern Gaul, see Cheyette 2008, 147-149. Interestingly, Roman ditches that had disappeared, were re-dug in the 12th and 13th centuries, a time when population increased again. [↑](#footnote-ref-69)
70. The Nile floods were determined by the climatic system of eastern Africa and the Indian Ocean, which is not directly linked to that of the Mediterranean. R. Ellenblum, *The collapse of the eastern Mediterranean. Climate change and the decline of the East, 950-1072*, Cambridge 2012, 24; Izdebski et al. 2016, 190. C. Elliott, ‘The Antonine Plague. Climate change and local violence in Roman Egypt’, *Past and Present* 231 (2016) 3-31, 23-28 discusses the link between volcanic eruptions, climate change and the increased frequency of insufficient Nile floods, seeing this as the main cause of the missing people, which has often been ascribed to the Antonine Plague. Newfield and Labuhn 2017, 221-227 criticize his “peculiar and dated” use of paleoscientific data, but do not reject his hypothesis. [↑](#footnote-ref-70)
71. McCormick et al. 2012, quotes pp. 183 and 189, also 203. Cf. Harper 2017, 133-134. [↑](#footnote-ref-71)
72. Harper 2017, 132. [↑](#footnote-ref-72)
73. D. Rathbone, ‘Price and price formation in Roman Egypt’, in: Économie antique. *Prix et formation des prix dans les économies antiques*, Saint-Bertrand-de-Comminges 1997, 183-244, 191; A.K. Bowman, *Egypt after the Pharaohs, 332 BC-AD 642. From Alexander to the Arab conquest*, London 1986, 94; M. Sharp, *The food supply in Roman Egypt*, Unpublished dissertation, Oxford 1998, 318f; R. Duncan-Jones, *Money and government in the Roman Empire*, Cambridge 1994. [↑](#footnote-ref-73)
74. Unfortunately, the only seemingly quantitative evidence contradicts all other indications. In his *Jewish War* (2.383, 386), Flavius Josephus makes Herodes Agrippa say that Egypt contributes sufficient grain to feed Rome four months, while Africa (“from the Pillars of Hercules to the Red Sea”) feeds the populace of Rome during eight months. However, Pliny (*Pan*. 31) says “it was generally believed that Rome could only be fed and maintained with Egyptian aid”. The passage occurs in a panegyric of the emperor Trajan, but the point of the wider passage is not to deny the crucial role of Egyptian tribute, but to reject the image of Rome’s dependence on Egypt. Hence, he emphasizes the shipment of grain to Egypt, when that province suffered from shortage. In more detail: P. Erdkamp, The grain market in the Roman Empire, Cambridge 2005, 226-230. [↑](#footnote-ref-74)
75. Erdkamp 2005, 249-255. [↑](#footnote-ref-75)
76. If the claim of the *Historia Augusta,* *Sept. Sev.* 8.5 (admitted, not a reliable source) that Septimius Severus built up stocks of grain amounting to seven years of tribute in Rome during his reign has any resemblance to reality, spoilage must have been a serious problem indeed. [↑](#footnote-ref-76)
77. J. Gustavsson, C. Cederberg and J. Sonesson, *Global Food Losses and Food Waste: Extent, Causes and Prevention*. Gothenburg FAO, 2011; R.J. Hodges, J.C. Buzby and B. Bennett, ‘Foresight Project on Global Food and Farming Futures: Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use’, *Journal of Agricultural Science*, 149 (2011) 37-45. On war-time logistics in Antiquity, see P. Erdkamp, *Hunger and the Sword. Warfare and food supply in Roman Republican wars*, Amsterdam 1998. [↑](#footnote-ref-77)
78. M. Wörrle, Ägyptisches Getreide für Ephesos’, Chiron 1 (1971) 325-340. Cf. P. Garnsey, *Famine and food supply in the Graeco-Roman world*, Cambridge 1988, 255-256; Erdkamp 2005, 234. [↑](#footnote-ref-78)
79. Erdkamp 2005, 230-235. [↑](#footnote-ref-79)
80. Josephus, *Ant. Iud.* 14.299ff; 15.306f. On later occasions, 20.51; 20.101. See Wörrle 1971, 334f. [↑](#footnote-ref-80)
81. See G. Hamel, *Poverty and charity in Roman Palestine, first centuries CE*, Berkeley 1990, 50f on date and parallel evidence. [↑](#footnote-ref-81)
82. A. Ben-David, *Talmudische Ökonomie. Die Wirtschaft des jüdischen Palästina zur Zeit der Mischna und des Talmud*, Bd. 1, Hildesheim 1974, 223. [↑](#footnote-ref-82)
83. Iv Tralleis 77; 80 = CIG 2927. Cf. Wörlle 1971, 335ff. [↑](#footnote-ref-83)
84. Iv Ephesos VII 1,3016. [↑](#footnote-ref-84)
85. R. Ziegler, ‘Münzen Kilikiens als Zeugnis kaiserlichen Getreidespenden*‘, Jahrbuch für Numismatik and Geldgeschichte* 27 (1977), 29-67, 34ff. [↑](#footnote-ref-85)
86. R. Alston, ‘Trade and the city in Roman Egypt’, in: H. Parkins and C. Smith (eds.), *Trade, traders and the ancient city*, London 1998, 168-202, 183. [↑](#footnote-ref-86)
87. Harper 2017, 259. Cf. Pliny, *Pan*. 31, who tells us that Rome sent grain to Egypt to alleviate a shortage there during the reign of Trajan. [↑](#footnote-ref-87)
88. Harper 2017, 162. [↑](#footnote-ref-88)
89. Harper 2017, 171. [↑](#footnote-ref-89)
90. See in particular D. Ch. Stathakopoulos, *Famine and pestilence in the Late Roman and Early Byzantine Empire. A systematic survey of subsistence crises and epidemics*, Farnham 2004, 205-215 for an overview and analysis of the sources on the events of these years. [↑](#footnote-ref-90)
91. Symmachus, *Relatio* III 15-17. [↑](#footnote-ref-91)
92. Ambrosius, *Epistulae* X 73, 17-21. Another source, Pseudo-Augustinus (Ambrosiaster), *Quaestiones* 115, *De* *Fato* 49, mentions shortages in Italy, Africa, Sicily and Sardinia, but of uncertain date. [↑](#footnote-ref-92)
93. Symmachus, *Epistulae* IV 74. [↑](#footnote-ref-93)
94. Prudentius, *Contra Symmachum* I vv. 920-954. [↑](#footnote-ref-94)
95. Symmachus, *Epistulae* II 6-7; Relationes IX, XVIII, XXXV, XXXVII. [↑](#footnote-ref-95)
96. Ambrosius, *De officiis ministrorum* 3.49; Ammianus Marcellinus 14.6.19. [↑](#footnote-ref-96)
97. Symmachus, *Epistulae* II 52. [↑](#footnote-ref-97)
98. Symmachus, *Epistulae* III 55. [↑](#footnote-ref-98)
99. See Stathakopoulos 2004, 209-210 for sources and discussion. [↑](#footnote-ref-99)
100. Irene De Soto, *The Economic Integration of a Late Roman Province. Egypt from Diocletian to Anastasius*. Unpublished dissertation. New York University 2018, 146. [↑](#footnote-ref-100)
101. Wickham 2005, 443-445, quote from 457; Izdebski et al. 2016, 191. Wickham 2005, 458 points to the disruption of the north-south exchange in the 7th century, causing decline in the Limestone Massif and the Negev. [↑](#footnote-ref-101)
102. Izdebski et al. 2016, 202. However, they also note (p. 205) that a decline in cultivation in the Levant appears to precede the shift in climate to drier conditions. [↑](#footnote-ref-102)
103. J. Poblome, ‘The economy of the Roman world as a complex adaptive system. Testing the case in second to fifth century CE Sagalassos’, in: P. Erdkamp and K. Verboven (eds.), *Structure and performance in the Roman economy. Models, methods and case studies*, Brussels 2015, 97-140, 120-123, 136. [↑](#footnote-ref-103)
104. Ibidem 133-134. [↑](#footnote-ref-104)
105. Izdebski et al. 2016, 205. Also, Haldon et al. 2014, 126-127. [↑](#footnote-ref-105)
106. Also Haldon et al. 2014, 138, 143, 147 date the waning of intensive exploitation of the land to the beginning of the 7th century. [↑](#footnote-ref-106)
107. Izdebski et al. 2016, 205. Compare Haldon et al. 2014, 144: “No simple correlation exists between societal collapse and any adverse climatic changes in the Nar Lake record during the seventh and eighth centuries.” [↑](#footnote-ref-107)
108. Haldon 2017, 228-229. [↑](#footnote-ref-108)
109. Weiberg et al. 2016, 40. [↑](#footnote-ref-109)
110. Weiberg et al. 2016, 51. Likewise, Bowes 192 notes that some surveys point to an increase in settlement and possibly population in some parts of Greece in the 4th and 5th century. [↑](#footnote-ref-110)
111. Weiberg et al. 2016, 51. [↑](#footnote-ref-111)
112. Recently, Alexander Sarantis, *Justinian's Balkan Wars. Campaigns, Diplomacy and Development in Illyricum, Thrace and the Northern World A.D. 527-65*, Prenton 2016.. [↑](#footnote-ref-112)
113. M. Morellón et al., ‘Human-climate interactions in the central Mediterranean region during the last millennia. The laminated record of Lake Butrint (Albania), *Quaternary Science Reviews* 136 (2016) 134-152, 134. [↑](#footnote-ref-113)
114. Morellón et al. 2016, 146-147. [↑](#footnote-ref-114)
115. Morellón et al. 2016, 149. [↑](#footnote-ref-115)
116. However, A.M. Mercuri et al., The Late Antique plant landscape in Sicily: Pollen from the agro-pastoral villa del Casale - Philosophiana system, *Quaternary International* (2017) 10 (https://doi.org/10.1016/j.quaint.2017.09.036.) mention a phase of cooling and moisture from AD 270-750. [↑](#footnote-ref-116)
117. Sadori et al. 2016, 173. [↑](#footnote-ref-117)
118. Sadori et al. 2016, 177. [↑](#footnote-ref-118)
119. E. Vaccaro, ‘Patterning the late antique economies of inland Sicily in a Mediterranean context’, in: L. Lavan (ed.), *Local economies? Production and exchange of inland regions in late antiquity*, Leiden 2015, 268-269; Sadori et al. 2016, 180-181. On the basis of pollen analysis, Mercuri et al. 2017 conclude a large degree of continuity of the agricultural landscape between the 3rd and 7th centuries. [↑](#footnote-ref-119)
120. Sadori et al. 2016, 182-183. [↑](#footnote-ref-120)
121. Sadori et al. 2016, 186. [↑](#footnote-ref-121)
122. Erdkamp 2005, ch. 6. [↑](#footnote-ref-122)
123. On the vici, Esmonde Cleary 2013, 140-141. [↑](#footnote-ref-123)
124. Tchernia 2016, 82-89 on the distribution of Mediterranean olive oil. [↑](#footnote-ref-124)
125. Ibidem, 102. See in particular pp. 103-114, and 265-276 on the commercial side-effects of the Egyptian grain supply of Rome. [↑](#footnote-ref-125)
126. Esmonde Cleary 2013, 311; T. Lewit, ‘The lessons of Gaulish sigillata and other finewares’, in: L. Lavan (ed.), *Local economies? Production and exchange of inland regions in late antiquity*, Leiden 2015, 229-230, 238-240. [↑](#footnote-ref-126)
127. One interesting case involves five *corpora* of shippers from Arles (*corpus navicularii marini Arelatenses*), known from an inscription (*CIL* III 14165/8) from AD 201. [↑](#footnote-ref-127)
128. AE 1979, 434 = Dardaine and Pavis D’Escurac (1986) nr. 12. [↑](#footnote-ref-128)
129. Cf. P. Sarris, ‘Integration and disintegration in the late Roman economy. The role of markets, emperors, and aristocrats’, in: L. Lavan (ed.), *Local economies? Production and exchange of inland regions in late antiquity*, Leiden 2015, 167-188, 174: “The Roman state can be seen to have catalyzed and fostered trade at both a regional and inter-regional level through its own fiscalised demands and the inter-regional mobilization of resources which it generated.” [↑](#footnote-ref-129)
130. Wickham 2005, 77; Esmonde Cleary 2013, 291-297, 311-312. Lewit 2015, 247 notes that military supplies on the Rhine and in Britain after the third century were local, while the Danube armies may have received supplies from the Aegean and Levant. [↑](#footnote-ref-130)
131. Michael Kulikowski, *Late Roman Spain and its cities*, Baltimore 2004, 55. [↑](#footnote-ref-131)
132. Lewit 2015, 232-233. [↑](#footnote-ref-132)
133. Esmonde Cleary 2013, 458-459. [↑](#footnote-ref-133)
134. Ibidem, 111. However, see also Kulikowski 2004, 33-38 who warns against interpreting the decline in the ‘epigraphic habit’ as a sign of a decline of the urban institutions. [↑](#footnote-ref-134)
135. Esmonde Cleary 2013, 141-142. [↑](#footnote-ref-135)
136. Cheyette 2008, 138. [↑](#footnote-ref-136)
137. John Drinkwater, *Roman Gaul. The three provinces, 58 BC – AD 260*, Orig. ed. 1983, London 2014, 226. [↑](#footnote-ref-137)
138. On the shrinking of towns in Gaul, see esp. Esmonde Cleary 2013, 26, 66-73. [↑](#footnote-ref-138)
139. P. Erdkamp, ‘Economic growth in the Roman Mediterranean world: an early good-bye to Malthus?’, *Explorations in Economic History* 60 (2016), 1-20. As Wickham 2005, 264 points out, direct intensive control by landowners only made sense when urban demand made capital intensive farming worthwhile. Hence, late ancient agriculture was largely performed by small-scale tenant and peasant farmers. He also notes that small-scale cultivators do not produce large and stable surpluses (p. 537). [↑](#footnote-ref-139)
140. Cf. Sarris 2015, 179. [↑](#footnote-ref-140)
141. M. Kelly and C. Ó Gráda, ‘Living standards and mortality since the Middle Ages’, *Economic History Review* 67 (2014c) 358-381. [↑](#footnote-ref-141)
142. The archaeology in late-ancient Syria, Palestine and Arabia still points to a complex economy of free market exchange. M. Whittow, ‘How much trade was local, regional and inter-regional? A comparative perspective on the late antique economy’, in: L. Lavan (ed.), *Local economies? Production and exchange of inland regions in late antiquity*, Leiden 2015. [↑](#footnote-ref-142)
143. Sarris 2015, 185: “In Rome’s northern and western territories in particular, the state and Roman social institutions played a fundamental role in regional economic development and inter-regional exchange.” As a reflection of the greater complexity of the economy in the East, Wickham 2005, 709-714, contrasts the multifocal urban network of the East with the single ‘tax-spine’ from Carthage to Rome in the West in the 4th century. [↑](#footnote-ref-143)
144. Wickham 2005, 443-446. [↑](#footnote-ref-144)
145. Ward-Perkins 2005, 104-108, 123-127. [↑](#footnote-ref-145)