The Ancient Mediterranean Environment between Science and History
edited by W. V. Harris

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W. V. Harris contributes to an ongoing, and indeed ancient, debate on whether and how greatly human activity affects the environment or even climate and, correlatively, how environmental change affects human history. The authors in this edited volume do not attempt a new grand synthesis; indeed, the implicit (and almost explicit) argument here is that no synthesis is as yet possible.

Holding a belief that the world's climate is for the most part stable or that it changes in ways determined by some cosmic-scale process (the Stoic conflagration or the like) would tend to make one think that, *a fortiori*, we humans are scarcely able to affect the climate, even on a small scale. On the other hand, a belief that climate is unstable opens up the prospect of human action having some determinate effects that are proportional perhaps to our technological power. Moreover, the kinds of effects anticipated might be influenced by one's view of the general nature of climatic fluctuations: if the world is trending in some direction, it might seem easier to amplify than to oppose the trend.

Cultures differ in their view of the world and its climate. Some see long-term, or even perpetual, stability; others expect a catastrophe or decline. Those outcomes may be attributed to divine powers and they may be ameliorated by human agency; for example, the ancient Egyptians and ancient Chinese seem to have believed that the stability of their environment was in part guaranteed by the right actions of their pharaoh or emperor. In early Greek thought, Hesiod described the world as degrading from Golden to Silver to Bronze to the current awful Iron Age, though he said nothing about environmental change *per se*. Conversely, Democritus proposed that worlds came

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and went by chance and that in our world humans had slowly advanced from an almost bestial state to control nature and form civil society. The random fluctuations of the atoms presumably allow for environmental and climatic change, on the one hand, and, on the other, there seems no bar to supposing that sufficiently powerful humans might affect the environment. Plato proposed a divinely ordered *cosmos*, yet allowed for catastrophic environmental harm, at least in myth [*Tim.* 22, *Crit.* 110–111]. Aristotle's world-order was perpetual and stable [*Phys.* 8.1], yet he too allowed for endogenous climate change, albeit slow [*Meteor.* 1.14]. Columella records that the Sasernae, father and son, writing on agriculture in *ca* 90 BC, had hypothesized that the precession of the equinoxes discovered by Hipparchus could explain an observed amelioration of climate that allowed viticulture further north than formerly [*De re rust.* 1.1.4–5: see Thibodeau 2008]. Ancient authors do occasionally allow for human-caused change, at least in small ways. For example, in allowing for endogenous climate change, Aristotle also claims that the canal joining the Red Sea to the Nile was never completed [cf. Herodotus, *Hist.* 2.158], because the rulers realized that it would salinize and thus damage the Nile. Aristotle's student Theophrastus claims that an actual (micro-) climate change has occurred: after the people of Larisa in Thessaly drained the swamp, the valley became colder, killing off the olive trees [*De causis plant.* 5.14.2–3]. In the first century AD, Petronius [*Satyr.* 99.3.1] claimed that 'snows cling longer to rough and uncultivated regions but the earth shines where it has been tamed by the plow, (and) the light snow melts away as you speak of it'[1] Much later, Pausanias [*Graec. desc.* 8.24.11] explains the silting up of some river-mouths (the Maeander at Miletus) in contrast to others (the Acheloos in Acarnania) by citing the amount of plowing performed along their valleys: more plowing yields more erosion.

The Christian synthesis, heavily influenced by Neoplatonism, asserted a *cosmos* that has been stable since its creation, within which catastrophes or alteration to the divinely instituted order could scarcely occur. (Outside the domain of monotheisms, cyclic theologies continued to insist that change was inevitable.) Within that synthesis, the lost paradise of Eden was the perfect environment compared to which the current corrupted Earth was, as Dante [*Inferno* 14.94–99] expressed it of Crete taken as symbolic of the whole

[1] *incultis asperisque regionibus diutius niues haerent, ast ubi aratro domefacta tellus nitet, dum loqueris leuis pruina dilabitur.*

fallen world, a desert waste: 'paese guasto…diserta come cosa vieta'.[2] Even the lengthy (*ca* 1300 to *ca* 1850) and widespread shift in climate identified in 1939 as the 'Little Ice Age' seems to have gone unnoticed by contemporaries as a change in climate, although many of the individual effects were commented upon.[3]

Despite that synthesis, beginning in the 15th century, some Europeans attempted to modify their environment on a moderately large scale, by constructing polders.[4] The Dutch (and German and English) residents of marshy river-delta regions around the North Sea by *ca* AD 1000 began to enclose their villages and fields with dikes as barriers against encroaching seawater. This represents an attempt to stabilize the local environment against what from the human perspective is a natural degradation. By about the middle of the 15th century, the Dutch were building dikes around shallow areas of the sea and then using windmill-driven pumps to drain those basins: this constituted the creation of a polder. The earlier polders were small, only a few dozen hectares, but by 1608–1612, with the carefully planned creation of the Beemster polder (71 km^2), regions as large as dozens of square kilometers were transformed from shallow sea to low-lying land. Larger but less successful efforts were undertaken in the fen-lands of eastern England. Opponents of the project argued that the change would contravene the will of God. These projects go well beyond the taming of nature through cultivation of fields and gardens.

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2 The *Inferno* was published *ca* 1316. Earlier, see Thomas Aquinas (*ca* 1268), *Summa theol.* 1.102.2, quoting John of Damascus (*ca* 710), *Expositio fidei* 2.11, 'temperate, pure, and exquisite atmosphere, and decked with ever-flowering plants'. A little before John, Isidore of Seville, *Etym.* 14.3.2, had similarly described Eden: 'It does not grow cold or hot there but the air is always temperate' (*ca* 625). All of this imagery goes back to Greco-Roman notions of the Blessed Isles: see Keyser 1993.

3 Matthes 1939, 520 identified the end of the period and gave it its name but saw it as commencing much earlier: 'we are living in an epoch of renewed but moderate glaciation—a "little ice-age", that already has lasted 4000 years'. Grove and Rackham 2001 present data showing that it affected the Mediterranean. Grove 2004 provides an extensive analysis of the worldwide data: see pp. 1–10, 371–402 for an overview and pp. 604–641 for an evaluation of the effects of the climate change.

4 My account here depends upon Wagret 1959, 58–114 =1968, 51–103; Ash 2007; Fleischer 2007; and Steenbergen, Reh, Nijhuis, and Pouderoijen 2009, 43–71.

The Christian cosmological synthesis began to crumble in the early 17th century when Galileo showed that the long-observed dark spots on the Sun were indeed changes in the Sun. That is, a heavenly body long considered immutable was shown to alter.[5] On the Earth itself, cyclic phenomena, diurnal, lunar, or annual, were of course well known; but people began to find evidence for degradation in the environment, apparently deriving the idea from Lucretius, *De rer. nat.* 2.1150–1174, which depicts the Earth as aging and running down.[6] The theory that human activity could or did lead to degradation of notable swathes of the environment became widespread by the 18th century [see Grove and Rackham 2001, 8–10]. That analysis was reinforced by the frequent deployment by 18th-century European thinkers of a rhetoric of perversity against proposed political or social innovations, rejecting proposals on the grounds that if carried out they would produce effects opposite to what was intended.[7] The assertion that human intervention in nature has perverse results is the same trope in a different context. (Whether in any given case it is an accurate analysis is a separate question.)

Several authors writing on America, however, argued that deforestation would have significant, although local, effects. Cotton Mather, the Puritan cleric and pamphleteer, hypothesized that American winters had become milder due to forest-clearing and agricultural activity:

> Our own Winters are, as observably as Comfortably Moderated since the land has been Peopled, and Opened, of Later Years. Our Snows are not so Deep, and Long, since the Progress that has been made, in the Clearing of our Woods; and our Winds blow not so much Rasours [i.e., razors]...

5 Shea 1970; Reeves and Van Helden 2010, reviewed in this journal in Miller 2012.

6 Rejected by Columella, *De re rust.* 1.*pr.*1:

> In their opinion, the soil was worn out and exhausted by the over-production of earlier days and can no longer furnish sustenance to mortals with its old-time benevolence.

Cf. Pliny, *Nat. hist.* 31.53: 'Indeed, destructive torrents often run together when the hills have been denuded of the trees that used to contain and absorb the rains'.

7 Hirschman 1991, 11–42, esp. 72:

> The perverse...sees the...world as remarkably *volatile*,...[in contrast to those who] view the world as *highly structured* and as evolving according to immanent laws, which human actions are laughably impotent to modify. [emphases in original]

He supported that by quoting Petronius, *Satyr.* 99.3.1, as above [Mather 1693, 42–43]. By the end of the 18th century, this opinion was common enough to elicit studies[8] such as Williamson 1770 especially. Thomas Jefferson, writing from Paris as minister from the United States, claimed in his *Notes on the State of Virginia*: Query VII. Climate [1785], that:

> A change in our climate, however, is taking place very sensibly. Both heats and colds are become much more moderate within the memory even of the middle aged. [Jefferson 2002, 135]

Other writers argued the opposite, that deforestation would augment the extremes of climate, especially Dunbar, who claimed that 'It is with us a general remark, that of late years the summers have become hotter and the winters colder than formerly' [Dunbar 1809, 48], and stated that the cleared region would allow the Sun to warm the soil more in the summer and block the winds less in the winter [49].

Despite that rhetoric of perversity, the Congress of Vienna (1814–1815) established the 'Zentralkommission für die Rheinschifffahrt' / 'Commission Centrale pour la Navigation du Rhin', an organization whose goal was the reshaping of a large tract of land (the Rhine valley) for anthropocentric ends.[9] Here is an example, then, of a deliberate and conscious attempt by people to alter a significant region of their environment, and one expected to succeed. The river was channeled and its flow optimized for shipping; large floods were predicted and have been an actual consequence.

At the turn of the 18th century, scientists studying the Earth and its living beings were divided between two grand theories, labelled 'catastrophism' and 'uniformitarianism'. According to the uniformitarians, the processes affecting the Earth and its living beings that could be seen in operation 'now' were the same ones, perhaps varying in degree, that had 'always' been operating. According to the catastrophists, in the remote past catastrophes of various kinds had greatly altered the surface and inhabitants of the Earth. A leading

8 See Thompson 1980; Fleming 1990, 2–5.

9 Cioc 2013, esp. 30: any river, and especially the Rhine,

> was 'wild' and 'unruly' and therefore in need of being 'tamed' or 'harnessed' or, alternatively, was an 'enemy' in need of being 'defeated'.

I am indebted to my brother, Rick Keyser (University of Wisconsin), for alerting me to the revealing work of Cioc.

proponent of the catastrophist model was Georges Cuvier, who demonstrated that the Indian and African elephants were two distinct species (Linnaeus had coalesced them), and that the Siberian mammoth was a distinct, and extinct, species, as was also the American mastodon; both the Siberian and American, he claimed, had been extinguished through catastrophe.[10]

Although the scientific consensus of the 19th century came to prefer uniformitarianism, Cuvier had established that extinction occurs and many more species came to be recognized as having perished. But it does not seem to have been widely considered, or even considered at all, that humans may have caused the extinction of the mammoth or mastodon—although beginning in 1833 the dodo of Mauritius was cited as an example of human-caused extinction [see Turvey and Cheke 2008]. In contrast, James Hutton's theory of the Earth (first published in 1788, and made more accessible by Lyell's work of 1830–1833) argued that catastrophes were rare and not globally significant—but also that the Earth was very old compared to recorded history [see Dean 1992]. Thus, according to the uniformitarians, there was little prospect of significant anthropogenic alteration to the environment.

During 1740–1820, the thinking on what are now understood to be glacial erratics evolved, which in turn (and perhaps influenced by the abnormally cold 1810s) led to the evolution during 1820–1835 of various theories of a former ice age that were synthesized in 1837 as a theory of multiple ancient ice ages by Agassiz and Schimper. The theory became widely accepted within 40 years.[11] So the regular scientific discourse now included the idea that the climate of large areas might change quite drastically, albeit without human intervention.

That thinking seems to have been aided by the observation, at that time unexplained, that the winters of 1815/16 and a few years following were notably more severe than prior winters. Benjamin Franklin had already hypothesized, in a paper presented in 1784, that volcanic dust and ash might cause large-scale cooling of the climate, on the basis of his observations of

10 Rudwick 1998, 13–24 annotates and translates Cuvier's paper from 1796 on elephants; two papers from 1806 on extinct and living elephants are likewise annotated and translated on pp. 89–97.

11 See Krüger 2013, 23–84 on erratics, 85–163 on the early theories of an ice age, 165–189 on Agassiz and Schimper, and 191–397 on the diffusion and acceptance of the theory.

the dust and ash of Hekla in 1783 and the subsequent hard winter of 1783/4 [Franklin 1789, 375–377]. However, although the explosion of Tambora in 1815 is the largest known volcanic eruption in several millennia [Oppenheimer 2003], few people in Europe or America were aware of the event and thus the contemporary explanations offered in those continents for the hard winters varied widely.[12] Nevertheless, there was a general recognition that the climate had somehow changed, at least temporarily and not for the better. The recognition doubtless reinforced any tendency to respond to suggestions for climate engineering, on however small a scale, with a rhetoric of perversity.

Meanwhile, the first suggestion of large-scale anthropogenic climate change had been made by Erasmus Darwin (grandfather of Charles Darwin) in his 1791 poem 'The Botanic Garden: 1. The Economy of Vegetation'. He suggested, both in verse (lines 497–548) and in his accompanying notes [Darwin 1791, 48–53], that the nations of Europe should unite to tow icebergs to the tropics, to ameliorate the climate. The proposal was received as an instance of hubris and was rejected both as impractical and ineffective or, if effective, then perverse [see Carroll 2013, esp. 214–215]. Nevertheless, the idea that humans could organize and act to affect the global climate had been broached.

The first prediction of large-scale anthropogenic effects on climate seems to have been by Joseph Fourier in 1824, who indicated that human activity might eventually warm the planet:

> *L'établissement et le progrès des sociétés humaines, l'action des forces naturelles peuvent changer notablement, et dans de vastes contrées, l'état de la surface du sol, la distribution des eaux et les grands mouvemens* [sic] *de l'air. De tels effets sont propres à faire varier, dans [162] le cours de plusieurs siècles, le degré de la chaleur moyenne; car les expressions analytiques comprennent des coefficiens* [sic] *qui se rapportent à l'état superficiel et qui influent beaucoup sur la valeur de la température.* [Fourier 1824, 161–162: cf. 1827, 592][13]

[12] See the citations in Klingaman and Klingaman 2013, 78–83 on sunspots, icebergs, the Great Comet of 1811, and the New Madrid quake of 1811/12, etc.; 240–243 on electric disturbances and icebergs.

[13] See Burgess 1837, 16:

The ‘pea-soup’ fogs of London, depicted by Dickens in *Bleak House* (1852) and others, demonstrated local effects on the environment from the burning of coal [see Brimblecombe 1982] but were simply considered a local effect. Svante Arrhenius determined a specific source of global warming when in 1896 he computed that increasing carbon dioxide in the atmosphere would warm the planet [see Weart 2008, 5–8].[14] The work of Fourier and Arrhenius was later corrected in the way that science regularly refines its results but the scientific consensus in the early 20th century remained against actual large-scale anthropogenic effects on climate [see Van der Veen 2000].

It was only in the decades after the close of World War II that a new consensus began to emerge, that humans might indeed affect the environment of a large region or even the world. Some of the factors leading to this were the development of nuclear weapons, which opened up the prospect of a world-destroying war (1945); the Great London Smog of December 1952; the recognition that widespread and intensive use of DDT to eradicate mosquitoes and thus malaria had also eradicated birds (1962); the banning of air-burst nuclear-weapons tests in order to prevent further spread of radioactive fallout (1963); the recognition that the widespread use of freons was depleting the ozone layer (1976); and, finally, the growing consensus that anthropogenic carbon dioxide was accelerating global warming.[15]

It was confessedly in this context that Hughes penned his book, *Pan's Travail: Environmental Problems of the Ancient Greeks and Romans* [1994, xii: cf. 2014, vii–viii], the work that opened the modern debate on whether the

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> The establishment and progress of human society, and the action of natural powers, may, in extensive regions, produce remarkable changes in the state of the surface <of the Earth>, the distribution of the waters, and the great movements of the air. Such effects, in the course of some centuries, must produce variations in the mean temperature [for such places]; for the analytical expressions contain coefficients which are related to the state of the surface, and have a great influence on the temperature.

At the very end of the article, Fourier concludes, speaking of the laws of heat-transfer, that ‘l’application de ces lois à des effets très-composés exige une longue suite d’observations exactes’ [167]: see Burgess 1837, 20 ‘but the application of these laws to very complicated effects, requires a long course of accurate observations’.

14 See also Weart 2015 http://www.aip.org/history/climate/co2.htm.

15 See Weart 2008, 19–154; 2015 http://www.aip.org/history/climate/summary.htm.

ancient Greeks and Romans had largely deforested and otherwise damaged their Mediterranean environment. The reviews were few but moderately positive [see McMahon 1994, Stiebing 1994]. Later responses were more negative [see Grove and Rackham 2001, 18; Brooke 2014, 272–275], yet not so as to prevent a second edition [see Hughes 2014].[16] The case made by Hughes was based almost entirely on literary sources taken *au pied de la lettre*,[17] and drew on a model of human behavior in which some humans lived in sacred harmony with nature.[18] A few years before his second edition appeared, he reiterated his case, arguing from charcoal studies, pollen studies, and computer modelling (as a selection of three out of the 'dauntingly rich' array of material).[19] In the one charcoal study that Hughes 2011 cites, charcoal from pottery kilns shows a shift from a brief first phase of using alder, ash, and elm (flood-plain trees), to a second phase of using various species of deciduous oak, to a third phase of using the evergreen oak species known as holm oak (*Quercus ilex* L.). Hughes interprets this as the succes-

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[16] The revisions included mainly:
- (a) the addition of three new chapters:
  - 9 'War and the Environment',
  - 12 'Natural Disasters' (plagues and volcanoes), and
  - 13 'Changing Climates';
- (b) the addition of some pages on the Athenian mines at Laurion [136–142];
- (c) the inversion of the order of chapters 7 and 8 ('Agricultural Decline' and 'Industrial Technology and Environmental Damage'); and
- (d) the citation of a number of new works.

[17] As Harris remarks in the book under review, 'Scholars still write books about the ancient environment that are essentially digests of what Greek and Roman writers *said* about the environment', in contrast to studies about what 'the environment in antiquity was actually like' [xx].

[18] See Hughes 1994, 24–26 / Hughes 2014, 25–27 on noble savages of the Paleolithic who live in 'balance' with their environment, in that they 'adapt to the local environment and use it without destroying it'; 1994, 32–35 / 2014, 31–35 on urbanism that has divided humans from nature and (in Mesopotamia) 'substituted an attitude of confrontation for the earlier feeling of cooperation'; and 1994, 35–43 / 2014, 35–42 for the claim that, in contrast, the less urban land of Egypt was more stable because their ecology was more stable, their religion viewed the forces of nature as sacred, e.g., in the god Osiris, and their science and technology were 'sacred'.

[19] Hughes 2011, 45–46 explicitly cites Grove and Rackham 2001 as the opposition. For the three methods, see 2011, 47–49 on charcoal, 49–52 on pollen, and 52–55 on modelling.

sive destruction of two forests, first that of the flood-plain trees and then that of the deciduous oaks. However, the sequence could also, and perhaps more accurately, be explained as the progressive use of better and better wood for charcoaling (either due to the increased skill or the increased prosperity of the potters): holm oak is favoured for charcoaling, the trees of stage two less so, and those of stage one the very least.[20] The one pollen study canvassed at length by Hughes 2011 concerned a site in the remote Middle Atlas, about 400 km south of Tangier, where the pollen diagram that he reproduces does show a slight and temporary dip in tree pollen, with a corresponding peak in grass pollen, around 400–500 AD, which Hughes takes as confirming the report in Lucan (*ca* AD 60) that Romans harvested exotic woods from Mauritania, and thus in turn confirming deforestation. The computer model that Hughes 2011 cites was a model of vegetation built on the basis of pollen studies and literary sources, which concluded that the Mediterranean was moister around 2000 years ago. It is difficult to see how this model confirms or refutes any hypothesis about forests.

The notion that some human group or other lived in ecological harmony with its environment has never been more than a hypothesis and is often merely an ideology. Neither the ideology (or hypothesis) of a long-lost golden age of simple ease, as in Hesiod, nor the ideology (or hypothesis) of a nasty and primitive brutality escaped by extensive effort, as in Democritus, is a model likely to provide insight into the human condition in the world. Here is a simpler hypothesis: human groups have always exploited their environment up to the limits of their technology and only when deleterious effects become clear and costly do they respond, and then minimally, precisely in order to deal with the immediate problems that actually affect their lives. That is, the human use of the world is anthropocentric.

Moreover, if the world and things within it operate in determinate and knowable ways, the prospect exists that people, possessed of sufficient power, might produce large effects on the world. That is in essence what is intended in the remark attributed to Archimedes: 'Give me a place to stand, and I will

[20] For an explanatory table of all these species (and others), see Grove and Rackham 2001, 52.

move the Earth'[21]—i.e., even the cosmically-centred and motionless Earth must have some finite weight and thus a single person, armed with a long enough lever (and a suitable fulcrum), could in theory displace it. So the question about ancient anthropogenic environmental change is that of the *degree* to which it actually did occur. The best way to determine that is to consult the available evidence or to gather more evidence, always being cautious in interpretation. That is what Grove and Rackham 2001 did[22] and what Harris and the others also do.

Grove and Rackham 2001 is based on empirical evidence about the Mediterranean region, ancient and modern, and considers many aspects. The authors show that the Mediterranean climate system is rare in the world and that it is hardly one climate but is composed of many biomes, few of them 'forest' in the sense of northern European or eastern American woodlands. Thus, they argue, it is easy for people familiar with other kinds of biomes (e.g., scholars from northern Europe and eastern America) to view the current state of the Mediterranean as 'obviously' damaged. A very common type of biome around the Mediterranean is the savanna (herbaceous zone with trees sufficiently sparse to leave an open canopy), which is not a damaged or a deforested region [Grove and Rackham 2001, 190–216]. The plants of any biome of the region have scarcely had time since the end of the last ice age to adapt to the unusual climate and what can be known of prehistoric and ancient distributions of plants in the area does not appear to indicate large changes during antiquity [Grove and Rackham 2001, 151–166]. Many of the plants appear to be adapted to growing through repeated fires [Grove and Rackham 2001, 217–240] and such fire-adaptations actually do occur in other areas, including some eastern American woodlands.[23] Furthermore, some of the effects attributed to deforestation appear to be regular aspects of the

[21] The remark is attributed to Archimedes in this form by Pappus (*ca* AD 300), *Coll.* 8.11.19 [Hultsch 1878, 1060], whereas Plutarch, *Vita Marc.* 14.7 records Archimedes as writing to Hieron of Syracuse:

> εἰ γῆν εἶχεν ἑτέραν, ἐκίνησεν ἂν ταύτην μεταβὰς εἰς ἐκείνην.
> If there were another Earth, he could move this one by going to that one.

[22] I am here also indebted to my brother Rick Keyser for introducing this work to me and for useful discussions about its significance.

[23] As shown, e.g., in Keyser, Brose, Van Lear, and Burtner 1996 and the recent synthesis in Brose 2014.

ecology of the region, appearing to an expected degree and not consistent with degradation, namely, erosion, delta-formation, and karst deserts.[24] The investigations by Grove and Rackham display a sensitive appreciation of the context of their data and of the range of its interpretations. Most of the demonstrable change (damage) has occurred since World War II, especially through intensive alteration—they blame especially the bulldozer and the building of dams. That is, the perception (for example, of Hughes) that the Mediterranean is a damaged ecology is often a retrojection of modern theory upon ancient evidence; i.e., it is essentially presentist.

Let us now consider the specific contributions of Harris and others. The book is divided into five parts with one to three papers in each part:

> Frameworks (two papers),
> Climate (three),
> Woodlands (one),
> Area Reports (three), and
> Finale (one).

In part 1, Malanima ('Energy Consumption in the Roman World') and Veal ('Fuelling Ancient Mediterranean Cities') take on the question of the energy usage of ancient Greco-Roman culture.

Malanima reprises his nearly simultaneous paper Malanima 2014, which is focused on early modern and modern energy usage, and here attempts to build a model of ancient energy sources and usage. He uses that to argue that by *ca* AD 150 the system was no longer able to support the rising population. It should be noted that all his calculations necessarily depend in part upon estimated values for quantities like population and energy consumption: as Harris himself points out [2–3], 'the facts upon which it is based are fragile'. (Moreover, Malanima is too optimistic, or presentist about Heron's 'steam engine' [22], which was no such thing [see Keyser 1992].) Still, it should be noted that for the period up to *ca* AD 150, Malanima's conclusion appears to be that the system was in equilibrium, i.e., that there was no serious degradation of the environment caused by the cutting of trees for firewood and charcoal.

[24] Grove and Rackham 2001, 241–305 on erosion, 328–350 delta-formation [328–350], and 312–327 on karst deserts, some expanding and some shrinking.

Veal considers the evidence provided by charcoal fragments, primarily at Pompeii (as a case study), where beech was the primary source (60% to 80%), and other hardwoods (oak, maple, hornbeam) as well as orchard trees were secondary. The data are interpreted as showing a decrease in the use of beech from the second century BC to the first century AD. But as Harris points out [3], this could be due to a shift upwards in the lowest elevation at which beeches will grow [Theophrastus, *Hist. plant.* 5.8.3 with Grove and Rackham 2001, 142]. Indeed, the decrease in the usage of beech can be read not as a sign of ecological stress but as evidence of prosperity: owners of orchards were becoming more prosperous and were thereby enabled to remove old trees in favour of planting new ones—and the wood created by this culling was used to produce charcoal. (I do not mean that this interpretation is right or even better than those of Veal or Harris but rather that it is at least as good and that there is no basis yet known on which to rule in favour of one over the others.)

In part 2, McCormick ('What Climate Science, Ausonius, Nile Floods, Rye, and Thatch Tell Us about the Environmental History of the Roman Empire'), Cook ('Megadroughts, ENSO, and the Invasion of Late-Roman Europe by the Huns and Avars'), and Manning ('The Roman World and Climate') consider the role of climate, stable or otherwise, in the history of the Roman Empire.

McCormick offers three case studies in connecting historical (i.e., textual) evidence with scientific (i.e., material) evidence. First [63–69] is an attempt to establish a precise dendrochronological date for Ausonius' poem *Mosella*, which is generally set by scholars in the range AD 268–375 based on historical references internal to the poem. McCormick connects Ausonius' description of the 'drought-stricken' ('arentem') town Dumnissus with precipitation anomalies reconstructed from tree-ring data to select the year AD 371. However, the year 375 was even drier, according to the reconstruction and McCormick's preference for 371 is based in part upon his evaluation of the strength of the historical arguments in favour of 370–371. Harris calls the result 'amusing' [4] and points out that Ausonius' description need not refer to any specific situation. A third interpretation, beyond that of Harris and McCormick, is possible: one can read the description as setting a contrast between Dumnissus watered only by rain, hence 'dry' and the next place, Tabernae, watered by a perpetual spring—always a subject of praise in Greco-Roman literature.

McCormick's second case study [69–81] concerns the pattern of climate across the Roman Empire, as follows. Roman expansion (*ca*100 BC to *ca* AD 150) occurred during a period of stable climate, which seems to suggest that the stability aided the expansion. Perhaps, however, the polities absorbed by the Romans during this 'expansion' might have seen matters differently—why would a stable climate make any of Numidia, Cyrene, Hispania, Palestine, Syria, Gaul, and Egypt *more* prone to conquest? Instability, then, marks the climate from *ca* AD 150 to *ca* 400, and McCormick suggests that the instability contributed to the impetus for the barbarian invasions—but why would instability strengthen barbarians in this era, when it was *stability* that strengthened the Romans in the prior period? This seems more like ideology ('stable Rome' *versus* 'chaotic barbarians') than analysis. A more useful result would seem to concern the annual Nile floods, which were less fruitful from *ca* AD 160 for almost 150 years (the records break off after AD 299): this must have at least afflicted the Egyptian poor (as noted by Harris [4]).

McCormick's third case study [81–87] involves the evidence for the cultivation of rye in the later Roman Empire, which he suggests may have been motivated in part by decreased early summer rainfall, an adverse growing condition to which rye is more resistant. There is indeed evidence for the shift in rainfall (and for a decrease in temperature, to which rye is also more resistant) but correlation is not causation. We may equally guess that Northern Europeans preferred rye due to its better cold-resistance, its better productivity on northern soils (unlike wheat, it does well on sandy or peaty soils), or even for ideological reasons (for example, 'rye is the grain that we Germans eat'), none of which would necessarily be chronologically limited.

Cook deploys extensive climatological data (with impressive colour maps and graphs) to argue that mega-droughts prompted the migrations and invasions of the Roman Empire by two peoples from the Eurasian steppe, namely, the Huns and the Avars. The climatological evidence for the multi-decadal droughts is well argued, with droughts inferred in *ca* AD 340–380, *ca* 450–490, and *ca* 540–560. However, there was also a multi-decadal drought in *ca* AD 240–290, with invasions of the Roman Empire by the Goths (*ca* 235–270), as well as in *ca* AD 50–100, with no large invasions of the Roman Empire. Moreover, the invasions by the Huns begin after the drought of AD 340–390 and last all through the intervening non-drought era of 390–450. The invasions by the Huns of the Roman Empire might simply be the Roman-recorded phase of a long, steady (and violent) expansion—earlier phases would have involved conquests by the Huns of peoples outside the Roman Empire and, hence, went unrecorded by Roman historians. Again, correlation is not causation but intense droughts may well have affected the lives of Eurasian steppe dwellers in various significant ways. Harris agrees and prefers modest claims [4–5].

Manning contributes a long and careful study on climate change around the Mediterranean from *ca* 300 BC to *ca* AD 800. Manning points out (as Grove and Rackham did) that climate in the Mediterranean is a complex matter [104] and that it is often easier to find and recognize evidence for adverse conditions than for good [106]. As with Cook, the emphasis here is on precipitation rather than temperature [107]. Manning [112–115] evaluates the evidence for the 'Iron Age Cold Period' (as some have named it), a century or two near 765 BC, and concludes that there is no easy way to ascertain causality: the climate shift may have influenced Mediterranean history of that period, or not. Likewise [116–117, n13], he argues that deforestation is hard to demonstrate but that 'there is undeniably a major human element involved' in changes to the environment. Manning [120–135] summarizes what is known about solar activity during his chosen period, supplying eight graphs and a summary chart. He spots correlations between certain periods of less stable solar behaviour and periods of cultural instability (the third century AD and the century around 600). In addition to solar activity, Manning, the director of the Cornell Dendrochronology Lab, offers a summary and analysis of what is known from tree-ring studies [136–145] and finds similar correlations with dry periods. It is, of course, not altogether clear that this is independent confirmation, since the precipitation data derived from the tree-ring data ultimately go back in large measure to solar effects on climate. But it is confirmation that the periods in question were times of ecological stress. Manning [146–153] summarizes what can be gleaned from speleothems, i.e., from oxygen-isotope ratios in speleothems dated by uranium-series radioisotopes. The oxygen-isotope ratios are difficult to interpret because they reflect not only temperature of the precipitation but other fractionation processes [146–147]. What Manning might have also mentioned is that obtaining dates of sufficiently high resolution to be historically useful is difficult due to the long half-lives of the radioisotopes involved (uranium and thorium). Indeed, the available curves do not correlate well with one another [148–149, Figures 16–17] so I doubt that any conclusions should be drawn. Manning's overall conclusion [153–158] is that the period *ca* 300 BC to *ca* AD 500 experienced a relatively stable climate in the Mediterranean. However, Manning [158–163] is careful to point out that the data are only broadly consistent in showing a long 'Roman Warm Period' (within which span are two shorter periods of ecological stress), and, thus, that at any finer level of resolution 'a coherent synthesis is clearly impossible'. He nevertheless attempts a century-by-century synthesis [163–166,167, Figure 21]. Harris [6–7] is skeptical regarding Manning's proposed correlations and favours his caution.

In part 3, 'Woodlands', Harris addresses the issue of 'Defining and Detecting Mediterranean Deforestation, 800 BCE to 700 CE' [173–194]. Harris argues for a limited deforestation in the environs of larger cities and that in many places there was effective forest management. As Grove and Rackham did, Harris rejects the simple dichotomy of 'forest' *versus* 'cleared land' [175]. Harris proceeds carefully through the several stages of his argument:

- 'Definition' [175]
- 'Destructive Forces' [176–177]
- 'Wood Shortages' [177–183]
  - textual evidence
- 'The Palynological Evidence' [183–186]
  - such evidence is spotty and complex
- 'Sedimentation and Erosion' [186–187]
- 'A Demographic Approach' [187–189]
  - he is cautious about recent work
- 'Woodland Management' [189–192] and
  - again, textual evidence that Roman landowners managed their forests
- 'The Impact of Climate Change' [192–193].
  - he argues that the current data are too spotty to be conclusive

Although he has considered these many aspects rather briefly, his conclusion is sensible: 'No extreme hypothesis about deforestation seems well founded, and there is no reason to believe in a generalized crisis' [193]. He advances four nuanced conclusions that may be summarized by saying that deforestation in the strong sense was episodic and localized.

In part 4, 'Area Reports', Kouki ('…The Example of Southern Jordan'), Ermolli, Romano, and Ruello ('…Neapolis and Elea-Velia'), and Keenan-Jones ('…Roman Central-Southern Italy') provide studies of environmental matters in three restricted zones. The paper by Veal on charcoal at Pompeii (part 1) might well have been placed here.

Kouki addresses 'Problems of Relating Environmental History and Human Settlement in the Classical and Late Classical Periods: The Example of Southern Jordan' [197–211], in particular around Petra. Harris summarizes her conclusion as being 'that patterns of settlement there do not conform to what the climate data might lead one to expect'—since the climatic variable studied by Kouki, precipitation, is not correlated with population density.

Ermolli, Romano, and Ruello study 'Human-Environment Interactions in the Southern Tyrrhenian Coastal Area: Hypotheses from Neapolis and Elea-Velia' [213–231] and attempt to reconstruct the landscape at different eras around the two cities that they study using pollen and soil studies. For Naples, they establish three levels, 'first millennium BC' (i.e., prior to significant urbanization), 'Greco-Roman Period', and 'Late Ancient' (the ancient port silted up *ca* AD 500). The pollen shows a wide variety of plants including a deciduous oak forest (first century BC to second century AD) as well as walnut trees, and especially plants of the cabbage family (but absent during the third century AD, when chestnut, olive, pine, and holm oak increased). The same three levels for Velia show large deposits of eroded soil at various times, especially in the third century AD, which the authors attribute to 'declining land use management'.

Keenan-Jones considers 'Large-Scale Water Management Projects in Roman Central-Southern Italy' [233–256]. He opens by arguing (on the basis of various other studies) that, in the area he is studying, the period *ca* 300 BC to *ca* AD 300 was marked by lower rainfall and yet greater flooding, and that therefore the flooding must be due to greater runoff caused by deforestation [234–239]. He provides two case studies, one on the *Aqua Augusta* [240–246] and the other on flood control in the Tiber [246–253]. The aqueduct was built by Augustus in 30–20 BC and supplied the towns of the Bay of Naples (from a source around 50 km east of Vesuvius); and its flow-rate cautiously estimated by Keenan-Jones would, he suggests, have had serious effects on the water supply of the source region. Tacitus, *Ann.* 1.79 records the plan proposed under Tiberius (AD 15) to control flooding on the Tiber by rerouting the Clanis (a northwestern tributary on the right bank of the Tiber) into the Arno and by dispersing the river Nar (a northeastern tributary on the left bank of the Tiber) into irrigation leats. Keenan-Jones analyzes the arguments against the plan recorded by Tacitus but concedes that we can no more draw conclusions about why it was abandoned than could Tacitus, who closes with an *aporia*, 'either the pleas of the <cities affected> or the difficulty of the works or superstition <about sacred rivers> prevailed'. From the two studies, Keenan-Jones concludes that elites were willing to propose and carry large-scale water-management projects but that they kept in mind the adverse impacts on their clients [253–256].

The 'Finale' (part 5) is provided by Wilson's 'The Mediterranean Environment in Ancient History: Perspectives and Prospects' [259–276]. He presents a cautiously positive summary of the papers within the book [259–273], and closes with a survey of 'Future Directions' [273–276], for example, to assess more carefully the relative effects of long-term change and sudden change such as that caused by volcanoes and earthquakes.

The book is thus composed of two kinds of papers: small positive contributions based on careful work in a carefully defined scope and attempts at larger syntheses of the sort that can be tested (Malanima in part 1, and Harris in part 3). This would be a summary of the positive contributions, each of which is one more piece of the giant puzzle: Veal's valuable data on the woods used to produce charcoal at Pompeii from the third century BC to the first century AD; McCormick's valuable analysis showing that the Nile floods were less fruitful *ca* AD 160–300; Cook's establishment that there were five multidecadal droughts during the first six centuries of the era; Manning's careful synthesis of climate data around the Mediterranean for 300 BC to AD 800; Harris' re-evaluation of the textual evidence for environmental change and management; Kouki's analysis of settlement and precipitation patterns at Petra; the measurement by Ermolli, Romano, and Ruello of silt accumulation in late antiquity at Naples and Velia; and Keenan-Jones on the attitudes of elites in the early Roman Empire towards large-scale water management projects.

There is an extensive and valuable bibliography [277–325] and a good index [327–332]. Misprints are few: for example, 'points out some of the reasons why such [are] hypotheses may be problematic' [5]; 'Figure 2' wrongly for 'Figure 1' on 23n39; and 'ice carrots' for 'ice cores', presumably an over-literal translation of the Italian 'carote di ghiaccio' in 24–25.

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