The Ancient Mediterranean Environment between Science and History

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DEFINING AND DETECTING MEDITERRANEAN DEFORESTATION, 800 BCE TO 700 CE

W.V. Harris

THE PROBLEM

Did the ancient Mediterranean world experience real deforestation? Opinion is divided.¹ In this paper I shall first attempt to clarify the problem (definition is essential), describing the destructive forces that were at work in the period from the rise of the Greek polis to the first phase of the Muslim conquests. I shall then consider the evidence for possible shortages of fuel-wood and construction wood, and make some comments on the markets in each of these classes of commodity. Next I shall briefly review the most pertinent evidence provided by pollen analyses and by alluvial sedimentation. I shall evaluate a recent discussion based on demography. I shall attempt to demonstrate that the reason why the effects of heavy demand for wood were not more severe was probably active woodland management combined with an effective system of distribution. Finally I shall consider the likely effects of known climate changes.

The substantive problem of deforestation arises here from the fact that the Greeks, Romans and other peoples of the Mediterranean certainly used and destroyed great quantities of trees. In the period 800 BCE to perhaps 165 CE, they cleared huge amounts of arable land. They were always very heavy consumers of timber: under the Roman Empire especially, the demand was heavy both for fuel wood (including fuel for the production of metals and glass), and for timber to be used for innumerable kinds of building and manufacturing. From ships to writing tablets, from spears to ploughs, almost everything was made of wood. The vast majority of fuel was wood,² often in the form of charcoal, and cremation was widespread until at least the second century CE. Those who do not believe that all this

¹ I thank Karl Butzer, Paolo Malanima and Robyn Veal for comments on an earlier draft of this article, and Milena Vasiljevic for useful information.
² See Harris 2011a, 108.
But see Veal in this volume, p. 37.
wood use had severe effects on Mediterranean woodlands have to emphasize that woodlands, in temperate climates at least, can regenerate themselves.³

Both periodization and definition are crucial to what follows. Periodization first of all: people began clearing tree-covered land during the Neolithic, and the larger kind of settlement could have serious consequences. Investigators of a key site in Jordan, for instance, have written of ‘dramatic local deforestation’ before 4500 BCE.⁴ By the third millennium BCE pharaohs were importing timber to Egypt by sea.⁵ Bronze Age changes in the environment have been widely recognized across the whole region. By 800 BCE, at all events, Mediterranean lands, especially in the east, are likely to have been much less tree-covered than they were at the beginning of the Holocene, though there is no way of quantifying this change. Population and economic production then intensified from the eighth century BCE till the second or third century CE—and what that did to Mediterranean woodlands is the primary subject of this paper.

What happened demographically and to production later on, say from 200 to 700 CE, is hotly disputed; I shall hypothesize here that by 450 both population and production had greatly decreased in Mediterranean Europe but less so in the eastern and North-African parts of the Mediterranean zone. And there is no natural cut-off point in the seventh century either. Thus the period discussed in this paper, while it consists of a time of intensified timber use, was neither preceded nor succeeded by periods of zero demand; far from it. We must also remember that demand for wood could rise and fall dramatically in particular regions independently of the trends I have been describing: Attica, for example, and some other parts of Greece too, were substantially denuded of tall trees in the era of Athenian naval power in the fifth and fourth centuries BCE, but Attica seems to have recovered to a notable extent when Athens lost its independence and its fleet.⁶

³ See Rackham 1996, etc. Much depends, naturally, on the local climate and geology, on how the land is treated (whether for example it is used for pasturage), and on the species in question (cedar forest, for instance, takes centuries to regenerate: cf. Rauh et al. 2009, 267). Conifers in general require reseeding/replanting from scratch.
⁴ ʾAin Ghazal, just north of Amman: Fall et al. 2004, 143; the climate was too arid to allow woodlands to renew themselves effectively.
⁵ Gardiner 1961, 42, Polzer 2011, 351.
⁶ Harris 2011a, esp. 123; Harris 2011b.
DEFINING AND DETECTING MEDITERRANEAN DEFORESTATION

DEFINITION

But what is deforestation?7 Not simply, in any case, ‘anthropogenic disturbance of the local forest ecosystem’,8 as when, because of human activity, one species supplants another.9

Part of the problem of definition is an excessively simple dichotomy between undisturbed woodland and cleared land. Everyone, or almost everyone, recognizes that landscape types are numerous in every climate zone, with differing quantities of open areas. We need at the very least a tripartite categorization of ancient Mediterranean landscapes, which should include a lightly wooded category, such as would sustain the everyday needs of an agrarian population. But whenever woodland was cleared away and stayed cleared away, that must count as deforestation, whether the result was farmland, scrub, or eroded hills, or any combination of these conditions. It will only fail to count as deforestation if, because of natural causes or managed re-growth, the effect was short-lived.

Normal usage, however, seems to reserve the term deforestation for cases that produce easily recognizable ecological crisis. And much of the argument about the Mediterranean environment is about who or what caused the ruined landscapes that characteristically occur when karstic limestone hills, stripped of their major vegetation, become seriously eroded. (Not that these are the only ‘badlands’). But some regrettable vagueness remains, and all that seems possible at the moment, in the context of ancient history, is to distinguish between deforestation that is more radical and that which is less so. It may be fair enough to describe the clearing of a certain area for farmland as an ‘episode of deforestation’,10 but episodes of this kind will only take us so far.

7 I have to leave aside here the differences that may exist between this term and similar concepts in other languages such as déboisement, Entwaldung, Abholzung, and disboscamento.
8 Hughes 2011, 49, appears to use this expression as an equivalent of deforestation. He claims (55) to have evidence of ‘major deforestation in many parts of the Mediterranean Basin in classical Greek and Roman times’, and that this deforestation ‘caused environmental damage contributing to the disruption of ancient economies’. For the latter kind of claim see above, pp. 2–3. There is indeed evidence of some deforestation in the Graeco-Roman Mediterranean, though as it happens the two studies from the 1980s that Hughes principally relies on do not provide evidence of this even for the localities in question (Planchais 1982; Lamb et al. 1989; see below, p. 184), but the reality is more complicated and less disastrous than he supposes. There have now been scores of palynological studies within the Mediterranean region.
9 With the exception, I suppose, that land planted with olive trees or fruit trees can be considered deforested.
10 Hughes 2011, 50.
Destructive Forces

What special factors tended to destroy woodland in the ancient world? The most obvious factor is population growth. Let us suppose that the population of the Mediterranean world rose from 20 million to 50 million by the second century AD, and that each person required on average the product of from 1 to 2 hectares of arable land; that meant at a minimum an additional 300,000 km² under cultivation. We might think that the amount actually cleared was larger by a factor of at least two and probably more. The land area of the Mediterranean Roman Empire, mountains, marshes, deserts and other uncultivable land included, amounted to approximately 2,700,000 km². So it begins to be quite evident that land-clearance made a major difference.

But it is a mistake to suppose that all pre-modern cultures have more or less the same per capita demand for wood. No one, admittedly, has so far succeeded in quantifying the Graeco-Roman demand for wood, or even for wood-fuel, in any impressively precise way. Consider some of the difficulties. It was metallurgy that required the truly lavish use of wood fuel in the Roman world, not the manufacturing of bricks or glass or the heating of baths, though all these processes required very large amounts. But we have only a quite vague idea of the overall scale of metal production. It is often said, for example, that the high Roman Empire is likely to have produced 80-85,000 tons of iron a year. 80,000 tons would have required the fuel produced by approximately 26,000 km² of coppiced land. 80–85,000 tons of production is unlikely to be a greatly exaggerated figure (the evidence of the Greenland ice-cores suggests that the production of metals in Europe did not reach Roman levels again until the Industrial Revolution), and it may well be too low, but in any case it is quite speculative.

I see no way of estimating in any useful way the amount of wood fuel that was needed across the whole ancient Mediterranean for metallurgy, brick- and glass-production and the heating of baths, but it was obviously enormous and continuous. It could of course be argued that the ancients would

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11 For the first figure see Morris et al. 2007, 9; I have not forgotten the sceptical comments of Cawkwell 1992 about population growth in archaic Greece.
12 For 1 hectare per head as the bare minimum needed for food and fodder, see Malanima this volume, p. 18.
13 Thus I disagree with Kaplan et al. 2009; see further below, p. 187.
14 The figure derives from a guess by Healy 1978, 196.
15 Harris 2011a, 119.
16 See the bibliography in Sallares 2007, 26.
not have been able to continue certain cultural practices, such as heating water for baths and cremating the dead, if prices had risen precipitously (and eventually cremation became less popular—see below).

Timber for construction sometimes seems to have severe effects, as we shall see below, especially during building-booms and when large navies had to be built. All the more so, because particular species were always preferred for shipbuilding and for any but the simplest on-land building. On the other hand, the volume of timber needed for fuel must vastly have exceeded the volume needed for construction.

Landowners and farmers must often have faced the dilemma of choosing between trees and animals (a slow return versus a faster return). All ancient Mediterranean people who knew anything about the countryside—the great majority in other words—were doubtless aware of the fact that trees and goats do not get along with each other (the classic text is a vivid fragment of Eupolis’ comedy *The Goats*). There are many other traces of this conflict in Greek and Latin literature. The trees must often have lost.

**Wood Shortages**

As far as fuel wood is concerned, most Mediterranean micro-regions probably remained self-sufficient at most periods. There were three exceptions to this pattern, possibly reduceable to two: (1) some areas of intense and prolonged metal-working, (2) the great metropolitan centres, and (3) Egypt, where however the root of the problem may have been Alexandria.

Athens, which had long before run short of ship-building timber, seems still to have produced much of not all of its fuel wood and charcoal in the late-fifth century and in the fourth, but it is known by a chance find to have imported fuel wood from Torone (on the north coast of the Aegean) in the third quarter of the fourth century BC, just in the period in which its Laurion silver mines became more active again. Together with other evidence, all this shows that Attica was probably quite severely deforested in the mid-fourth century, but several centuries later it seems to have recovered

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18 See Veal, this volume, p. 40.
22 See the letter reported in *SEG* 43 (1993), no. 488, with Harris 2011a, 123 n. 89.
to a considerable extent.\footnote{See Pausanias 1.32.1.} Simply to cite one other case, it is reasonably clear that Elba eventually ran short of fuel for processing its iron ore, so that the processing had to be carried out at least in part on the mainland.\footnote{Contrast Diodorus Siculus 5.13 with Varro (ap. Servius, \textit{Verg.Aen.} 10.174) and Strabo 5.223 (cf. Ps.-Aristotle, \textit{On Marvellous Things Heard} 93). Corretti and Firmati 2011, esp. 229, show that iron production on the island itself had largely ceased by about 50 BCE.} But the normal pattern of Greek and Roman production of metal goods was that ingots of the raw material were transported to centres of demand.\footnote{Harris 2000, 723.} That meant that every prosperous community, in every part of the region, required fuel for the actual manufacturing processes, Tebtunis with its much-differentiated metal-workers as well as the towns of high-imperial Italy.

Rome and Alexandria had to draw on areas beyond their immediate hinterlands. The construction of the \textit{porticus inter lignarios} outside the Porta Trigemina at Rome in 192 BCE\footnote{Livy 35.41.10.} occurred at a time when the city of Rome was growing very rapidly and its location suggests that the \textit{lignum} in question was coming up the Tiber, not down it as we might have expected;\footnote{This view is fortified by Tucci’s demonstration (2004, 199) that the Pons Sublicius (and hence in all likelihood the Porta Trigemina) was lower down the river than recent doctrine has maintained.} it would be reasonable to conclude that the lower Tiber valley was no longer rich in timber (the era of carefully-managed Italian woodlands had perhaps not yet begun). We can only speculate about where the famous \textit{navicularii lignarii} of Ostia found wood fuel to import near the end of the second century CE (Sardinia perhaps).\footnote{The inscription: \textit{CIL} 14.4549. The date: Meiggs 1982, 339.} In the fourth century, under Valens and Valentinian in the 360s, Rome was importing fuel from North Africa; it may have been the huge baths of Diocletian and Constantine that necessitated this.\footnote{The main texts are \textit{C.Th.} 13.5.10, 14.5.1. See further Harris forthcoming.} We shall see later that evidence from Antioch suggests that by the second century CE it was running out of local fuel, and the same may well have applied to other ‘second-tier’ cities such as Pergamum.

As for Egypt, there seems by Severan times to have been a chronic shortage,\footnote{See Ulpian in \textit{Digest} 32.55.5 ‘in Aegypto, ubi harundine pro ligno utuntur …’, ‘where they use reeds in place of wood’.} to such a degree that fuel wood was sometimes even imported from
Italy,\footnote{P. Tebt. II.686 (second or third century). It may have been transported by grain ships returning from Ostia to Alexandria (via the Calabrian coast). Whether we can associate fuel shortage with a decline in brick production in Italy after Severus Alexander (there was a recovery under the tetrarchy) or with the large-scale change from cremation to inhumation is regrettably obscure (Meiggs asserts the one possibility while denying the other [1982, 504 n. 119 and ib. 257]; I incline to the opposite view). However the whole notion that cremation ceased, or largely ceased, in the Roman Empire as a whole is in need of revision: in some provinces it certainly did not – see for example Pop-Lazic 2002.} the actual deforestation, however, may pre-date the period under investigation here.

With regard to construction timber (Lat. \textit{materia}), the story is quite different. The earliest signs of local shortage concern naval power. By the late fifth century, and probably earlier, Athenian naval hegemony depended on importing ship-building timber from Macedon and Thrace; it was out of the question to rely on Attica itself,\footnote{For the evidence for Attic deforestation to be found in Plato, \textit{Critias} 111c, see Harris 2011b.} all the more so because particular species were required. Here is the well-informed Theophrastus:\footnote{\textit{Hist. Plant.} 5.7.1–3.}

fir, mountain pine and cedar are the standard ship-timbers. Triremes and long ships [i.e. warships] are made of fir because it is light, while merchant ships are made of pine because it does not rot. Some people, however, make their triremes of pine also, because they are short of fir .... These woods are used for the main timbers, but for the trireme's keel oak is used .... They make the cutwater ... and cat-heads, which require special strength, of ash, mulberry or elm.

Theophrastus shows in fact that there was a serious lack of ship-building timber in Greece by the late fourth century BCE. ‘There is only a small area [he means in the eastern and central Mediterranean] which produces wood suitable for ship-building’: in Europe, Macedon and certain parts of Thrace and 'Italy', in Asia, Cilicia, Sinope, Amisus, and Mounts Olympus and Ida (but they do not have much); Syria has cedars, which they use for warships’.\footnote{Hist. Plant. 4.5.5. This might be taken to imply that Xenophon's report (\textit{Anabasis} 6.4.4) of ample ship-building timber at Calpe, on the Bithynian coast far to the west of Sinope, was now out of date. Italy for Theophrastus still meant Calabria; he underestimated the resources of the rest of the peninsula, which he had not apparently visited. He wrote this very early in a period of about a century during which, because of the number and increasing size of warships, the long-timber supplies of the eastern Mediterranean were put under greater strain than ever before or later; cf. Meiggs 1982, 139.} The other large naval powers of the high-classical Greek world—Syracuse, Corcyra, and above all Corinth—are likely to have encountered problems similar to those of Athens.
Theophrastus tells a somewhat similar story about long timber ‘for the builder’s needs’, but there is a significant difference, because here he is concerned with quality not availability: the main cities of European Greece had to import the best building timber from Macedon, the Black Sea and other places, but rustic Euboea produced some building timber even though it was of poor quality.\textsuperscript{35} Such evidence as we have for the sources of timber listed in various fourth-century temple-accounts shows that Arcadia and even such a centrally located place as Sicyon could still provide some long timber.\textsuperscript{36} We might conclude that most but not all of mainland Greece, Sicily, the Aegean islands and the west coast of Asia Minor had lost most of their tall trees by about 310 BC, leaving them with simply enough coppiced trees and shrubs to provide fuel. Outside Attica, however, we have no strong reason to suspect ‘ruined landscapes’. Mount Lebanon meanwhile was rich in timber, cedar and cypress especially, when Antigonus set out to build a fleet on that coast in 315.\textsuperscript{37}

Ptolemaic Egypt was far from self-sufficient in this respect. Since this had probably been true of Egypt since the second millennium BC if not earlier, there is no need to set out all the evidence. Naval power, not to mention the building of Alexandria itself, depended on timber from overseas possessions, in particular Cyprus.\textsuperscript{38} In Egypt’s Greek period, the government’s concern is well attested from the middle of the third century, and one has the impression that in Greek and Roman times every tree in Egypt was under surveillance.\textsuperscript{39} Regulations promulgated by the king in 118 BCE show not only that it was illegal to fell a tree on private land without permission but that the occupiers of some legal categories of land had some obligation (not explained in detail) to plant trees.\textsuperscript{40} The most interesting fact, however, may be that a region possessing only minimal quantities of harvestable long timber could in fact manage reasonably well within the broader Hellenistic

\textsuperscript{35} Hist. Plant. 5.2.1.  
\textsuperscript{36} Meiggs 1982, 423–457, reviewed this evidence in detail, but I do not share his confidence that a timber-seller’s geographical origin reveals where his timber came from (there are too many Corinthians). The most interesting evidence from our point of view comes from Delphi, showing among other things that the rebuilders of the temple of Apollo could obtain seventeen cypresses from Sicyon in 335, but at ‘exceptionally high’ prices (Meiggs 431).  
\textsuperscript{37} Diodorus Siculus 19.58.  
\textsuperscript{38} Meiggs 1982, 133–135.  
\textsuperscript{39} On all this see Cadell 1976, 346, and Kramer 1995, 218–222. But note that the government was interested in trees partly because of their importance for the security of dykes: Drew-Bear 1995, 3–4, and P. Tebt. III.703 (second half of the third century BCE).  
\textsuperscript{40} Select Papyri II.210 = C.Ord.Ptol. 53, lines 200–206. (This depends on whether the ‘plantings’ referred to have to be trees).
and Roman economies, helped by a wheat surplus, the de facto papyrus monopoly and other advantages. But ambitious ship-building required the control of territory elsewhere, and that was why M. Antonius gave Cleopatra the territory around Hamaxia in western Cilicia. 41

Long before this time the Romans had come to dominate the Mediterranean Sea, having paid careful attention to the supplies that they needed for naval warfare. 42 Their naval history started from small beginnings in the late fourth century and reaching a crescendo at the Battle of Myonnesos, off the Ionian coast, in 190. Fortunately for Rome and for the Mediterranean woodlands, the interests of imperial power seldom thereafter required the deployment of a large fighting navy.

The evidence about Italy is a little mixed, but as it stands now it suggests an intensifying shortage of tall trees in early imperial times (further research on Campanian and Ostian architectural timber might possibly validate or invalidate this conclusion). When Dionysius of Halicarnassus, a worshipper of Rome, lauds the woodlands of Italy, claiming in particular that they provide ample timber for ship-building, he is demonstrably exaggerating, and committing something of an anachronism. 43 Other evidence suggests that some areas of Italy became more and more dependant on long-distance imports. 44 A text of Strabo about Pisa points in this direction: most of the timber in the Monti Pisani ‘is now [in Augustan times] being used up’ for construction at Rome and elsewhere. 45 This is what was likely to happen when there was long timber fairly close to a good port. But Strabo also says that most of Rome’s building timber comes down the Tiber from ‘Tyrrenia’. 46 Somewhat later the situation seems to have changed: some of the fir and spruce (picea sp.) from the Campanian cities came far away from the Austrian Alps. 47

41 ‘Since it was suited to the building of fleets’, Strabo 14.669. He is somewhat vague about the extent of the region in question. This was also how she obtained Rough Cilicia (ibid. 670), presumably.
42 It is symptomatic of this concern that at some early date the state took title to all coastal woodlands (Cicero, De rep. 2.58—he attributes the measure to King Ancus Marcius).
43 Dionysius of Halicarnassus, Roman Antiquities 1.37.4 (taken literally by Nenninger 2001, 200). It was quite untrue, for example, that Italy had ‘mines of all kinds’, 1.37.5; cf. Brunt 1971, 128–129. And he is plainly inaccurate when he says (20.15) that the Sila suffices for the needs of Italy.
44 I leave aside the matter of super-luxurious tables made of citrus-wood (Callitris quadrivalvis) imported from Mauretania, a fashion that led to the deforestation of the ‘Mons Anconius’ (Pliny, NH 13.95).
45 5.223, mistranslated by among others Grove and Rackham 2001, 173 n.
46 5.222.
47 Kuniholm 2002, 236–237 (dendrochronological evidence). It is a pity that the researchers in question did not check samples from Liguria, since that would be a more
The elder Pliny thinks of hills freshly stripped of trees as a common phenomenon: ‘springs often arise when woods have been cut down ... [he refers to an incident from Greek history] ... harmful torrents often run together when the woods which used to hold and absorb the rains have been stripped from the hills’, 48 It is quite wrong to cite him as a witness to the supposed fact that there had been widespread deforestation, 49 but the frequent allusions in Natural History Book 16 to sources of timber such as Raetia, Histria and Corsica that are just outside the Italian peninsula, 50 suggest that certain species at least were not readily to be had nearer at hand, even though he also mentions the Appennines. Elsewhere he alludes to logging in the upper reaches of the Tiber, and he mentions the silva Sila. 51 The source areas mentioned by Pliny are thus, in the main, well removed from the densest concentrations of population. 52

There may be other signs too of an eventual shortage in the area of the metropolis: Ulrich has pointed out a difference in construction practices between the Vesuvian cities in the first century and Ostia in the second—the latter used less timber, perhaps, as he suggests, because the supply of long timber was now under stress. 53

Emperors always owned a good deal of woodland, 54 but the only ambitious attempt by an emperor to look after the supply of long timber seems to have been an elaborate initiative undertaken by Hadrian in the province of Syria. In the northern half of Mount Lebanon, he had markers put up over vast areas of forest. There were at least 800 such markers (they were

plausible source. Robyn Veal (pers.comm.) shares my doubts about the Alpine source, noting that Picea grows in Liguria and Tuscany (Pignatti 1982, I, 74–75).

48 NH 31.53.
49 Hughes 1983, 437, on the basis of NH 13.65 (together with Livy 9.36), completely misrepresented (the Pliny passages refers only to a supposed silvestris regio near Memphis; actually the whole passage about trees in Egypt, sects. 60–65, is an intriguing one).
50 Raetia (sects. 66, 190), Histria (66), Corsica (71, 197). The other places he mentions are Macedonia, the Pyrenees, some specific zones of Asia Minor and Gaul, the Tyrrenian coast of Italy (meaning Liguria?), the Alps and Appennines, Crete, Africa, Syria and the land of the Vaccaei in Spain.
51 NH 3.53, 74.
52 It is intriguing that a resident of Italy such as Hermas (first- or second-century) seems to have been familiar with tree-less mountains (see at length Parable 9.1 and 9.19–29 in the Shepherd); he sets the scene in Arcadia simply because it was famously mountainous.
53 Ulrich 2007, 121. An interesting topic which we are not (or not yet) in a position to clarify, is why certain places, Gades for example, became ship-building centres at certain periods.
54 But I would not go as far as Thonemann 2011, 280, according to whom ‘throughout antiquity ... large and potentially profitable stretches of woodland were normally regarded as state property’.
often numbered), reserving four types of trees as imperial property. This *definitio silvarum* obviously shows that the emperor or some powerful subordinate regarded these forests as a valuable resource (and one recalls that Hadrian travelled in this region in 129–130). It seems unlikely that he would have intervened if he had not thought that the Mount Lebanon timber was at risk; the exact nature of his concern is unknown, but military preparedness, Mediterranean shipping and imperial building plans may all have come into it.

Under the high Roman Empire, there is good deal of evidence about shortages of long timber in certain areas, but nothing on the other hand that would justify diagnosing widespread deforestation throughout the Mediterranean.

**The Palynological Evidence**

Pollen deposits may one day settle the issue at hand in a definitive fashion, and over some thirty plus years studies of this material have proliferated in many Mediterranean regions—though not in some of the areas where they would be most interesting, such as Tunisia, Appennine Italy, Sicily, and Dalmatia. This evidence comes with various caveats, however. When woodland begins to be used for grazing rather than being displaced by cultivation, it may be hard to detect in the pollen record. Furthermore, many pollen studies concern more or less remote areas that are of secondary importance for the overall problem of deforestation. And it is only recently that it has become feasible to take proper account of three important variables, the pollen productivity of different species, the ‘fall speed’ of different kinds of pollen, and the prevailing winds at the various sites in question. Research that takes inadequate account of these variables may be next to useless. Then there is the problem of low-resolution chronology.

However the following results, set out here very briefly, have seemed to emerge.

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55 See *IGLS* VIII, 3, edited by J.-F. Breton; at least 187 of these inscriptions have been recorded. There are now dozens more: *AE* 2006, 1572 f.
57 For other comments on this evidence see Harris 2011a, 130–131.
58 It is regrettable that there is no thorough up-to-date bibliography. Di Rita and Magri 2009 is useful from this point of view.
59 Atherden 2000, 64–66.
60 See Poska and Pidek 2010.
61 For a more detailed but already somewhat outdated survey see Harris 2011a, 133–136.
(1) In a number of places, both the Bronze Age and the later spread of Greek agriculture sharply reduced arboreal pollen; there is good evidence to this effect from, for example, bronze-age Miletus and the early Hellenistic Golan Heights. In Acarnania about 800–600 BCE there was a marked change in vegetation, obviously to be connected with increased human presence. Whether any of this amounted to deforestation seems to me to be to some extent a matter of definition. Unfortunately the areas most likely to have suffered deforestation in classical Greek and Hellenistic times, such as Attica and the hinterland of Alexandria, have no palynological evidence to offer, as far as is currently known.

(2) The Roman Empire witnessed the serious depletion of some woodland resources, and the effective management of others. Here in fact is our central problem—was the former pattern widespread? We have already seen some textual evidence that may make us suspect that it was so. Recent pollen research has detected this effect at Miletus, in coastal Puglia, and in north-western Iberia. Older reports make similar claims about, for instance, sites on the coasts of Catalonia and Provence. Pollen research

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62 See Knipping et al. 2008 (Bafa Gölü, Miletus) and Neumann et al. 2007 (Birkat Ram, northern Golan Heights). This is how I would interpret the ‘marked retreat of forest vegetation’ (Gerasimidis 2000, 35) at Lailias in the mountains of Macedonia (1420 m. a.s.l.) in the second century BCE; if the Romans had anything to do with it, it may have been because they brought this district into the timber market (the Strymon valley was not far away).

63 Jahns 2005 (Lake Voulkaria; the main feature was a big increase in Phillyrea, a genus of small flowering evergreen tree).

64 Knipping et al. 2008.

65 Di Rito and Magri 2009. They say that an accelerated decline in arboreal pollen took place at 2100 BP, but their Fig. 3 seems to date the event about 2300–2200 BP. They do not, however, apply the term deforestation to anything that occurred in Roman or late-Roman times.

66 Mighall et al. 2006.


68 Planchas 1982. Hughes 2011 relies heavily, though indirectly, on this study as evidence for Graeco-Roman deforestation. Planchas showed that pollen recovered from a site near the Étang de Mauguio (43° 35′ N) in Provence demonstrated a sharp contrast between a millennium-long period (roughly 2270–1300 BP) and what came before: the former showed lots of beech and oak, whereas the only trees well represented in the latter period were walnut and olive, and non-arboreal pollen (Typhaceae and Cyperaceae as well as Gramineae) was abundant. In other words, the local population and/or the Romans massively changed the pattern of local vegetation (be it noted that there was a huge amount of Roman centuriation nearby, though not in the immediate vicinity). Another study cited by Hughes, Lamb et al. 1989, discussed a site in the Middle Atlas in northern Morocco; these authors unfortunately wrote a misleading abstract in which they asserted that ‘anthropogenic forest degradation dates from about 2250 BP’, a date, be it noted, when the local economy had nothing to do with
also seems to show, however, that at Sagalassos in Anatolia, at a site deep in the Libyan desert, and at another high up in the Alps, to name three relatively clear examples, Roman practices did not have a strongly negative effect, if any at all, on the local tree population; but the last two of these sites can easily be regarded as peripheral.

(3) Late antiquity presents a similarly complex array of evidence. In some places woodlands grew back: at the site in the Golan Heights already referred to, olive cultivation collapsed in the first half of the seventh century and *Quercus calliprinos* expanded. But the same period seems to have been quite harmful to trees in some places, for example in Spain, in spite of an economic shrinkage that might have permitted woodland regeneration: at a site in the north-west of the peninsula, both total arboreal pollen and the percentage of pollen attributed to *Quercus* seem to be declining in the approximate period 550–750 CE; at sites on the Catalan coast, there is considerable evidence of a decrease in arboreal pollen in the period 500 to 700 CE, and the reduction in woodland led to erosion (the investigators proposed to associate these changes with an increase in grazing). At the site in Puglia mentioned above, olive trees come to dominate the pollen evidence more and more in late antiquity, especially after about 500 CE, while ‘most trees keep their declining trend’, was this trend owed to Byzantine demand for the region’s olive oil? It seems obvious, in short, that as far as the pollen evidence is concerned we cannot yet generalize about the whole Mediterranean world in late antiquity.

If Mediterranean woodlands suffered in the period 500–700 CE, climate change may have been partly or wholly responsible (a more arid climate may have prevailed—see below), but we do not yet know enough to assert this with any confidence. Another possible explanation might be a decline in the quality of land-management. The violent disruption of the barbarian

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69 See respectively Vermoere et al. 2003; Hunt et al. 2001; Moe et al. 2007 (the area in question is between 1830 and 2304 m. a.s.l.). The same seems to be true at Lake Voulkaria in Acarnania (above, n. 63).  
70 Neumann et al. 2007, 340.  
71 Mighall et al. 2006, esp. 209 fig. 3.  
72 Riera-Mora and Esteban-Amat 1994, esp. 20–21. The key sites were at Ullastret (decrease in AP values at 1500 +/- 80 BP) and at Besós (‘not much before 1300 +/- 40 BP’).  
73 Di Rita and Magri 2009, 300.
invasion, especially in the early fifth century, may have made careful, long-
term estate management a rarer phenomenon. (There is admittedly some
dispute about the whole nature of these invasions).

(4) Being close to water-borne transport under the Roman Empire meant
economic opportunity and also ecological trouble (contrast for example two
sites in the Alps, the Lac de Praver near Grenoble,\textsuperscript{74} with excellent access
to river transport, and Val Febbraro in the province of Sondrio,\textsuperscript{75} with very
poor access). But this statement has an important corollary: much of the
woodland of the Roman Empire, even in Italy, not to mention the Danube
and other provinces, was beyond the range of affordable water-transport,
and was therefore relatively safe from deforestation. A wooded area well
away from water-borne transport, such as the Troodos Mountains in Cyprus,
was to some extent protected from exploitation.\textsuperscript{76}

**Sedimentation and Erosion**

Erosion is a very large topic in the geological literature, but here I sim-
ply want to ask whether any of the resulting sedimentation in the Graeco-
Roman Mediterranean can be traced to deforestation within the period we
are examining. This is widely assumed to be the case, but precise chronology
has generally been lacking.

Recent literature has provided some relatively precise sites in Turkey.
Results from the hinterland of Antioch on the Orontes are especially inter-
esting. A recent investigator has shown that in the Jebel al-Aqra region
immediately to the east of Antakya, after millennia of human habitation,
severe erosion set in from about 150 CE onwards. In keeping with current
trends, he attributes this partly to climate and partly to land-use practices,\textsuperscript{77}
but in a moment of candour he admits that there is no correlation with any-
thing we know about climate change in the Levant.\textsuperscript{78} It is reasonably obvious
that for centuries after its foundation in 300 BCE Antioch managed its need

\textsuperscript{74} Nakagawa et al. 2000.

\textsuperscript{75} Moe et al. 2007.


\textsuperscript{77} Casana 2008. The ‘400-year lag between the initial settlement of upland areas and the
first evidence of soil erosion suggest[s] that it may have been the intersection of extreme
precipitation events with particular land use conditions of the Roman and late Roman
periods which worked together to drive soil erosion’ (429).

\textsuperscript{78} Casana 437.
for fuel-wood without severely deforesting the nearby hills (the area in question is between 7 and 14 kms. from the centre of the city), but eventually the situation got out of hand; given a population of perhaps 250,000 in the second century, that is hardly surprising—and the greatest density of settlement in this particular areas, together with the worst erosion, was still to come (from about 300 to 600 CE). 79

An earlier study, concentrating on south-western Turkey, detected similar effects in a more vaguely defined ‘classical period’, offering as an example the area between Burdur and Elmali, that is in ancient terms between Lycia and Pisidia. 80 Sedimentation at Lake Bafa, near to ancient Miletus in western Turkey and to the mouth of the River Maeander, reached a peak in the period from the first century BCE to the fourth century CE. 81

A Demographic Approach

In a previous article I implied that known population growth must have led to massive woodland clearance in the period from 800 BCE onwards, but also that this approach cannot by itself settle the major question about ancient Mediterranean deforestation. 82 Meanwhile, in a paper entitled ‘The Prehistoric and Preindustrial Deforestation of Europe’, published after mine went to press, Kaplan, Krumhardt and Zimmermann made a resolute and more optimistic attempt to come at the deforestation problem from the angle of demography. 83

They estimate the population of ancient Europe and most of the Mediterranean, posit the amount of arable land that would have been necessary to support these populations (taking account of climate and of soil properties); that, according to them, was the amount of land cleared and deforested. Their population estimates for ancient times are mostly reasonable ones (and we can overlook the incongruity of their claim to know what the population of, say, Belgium was in 1000 BCE; they insist on using modern territorial units). 84 And it is a positive aspect of this study that its authors take account of soil properties and climate change.

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79 Casana 433.
80 Roberts 1990.
81 Knipping et al. 2008. On possibly related changes in the rural economy of Miletus in the first century BCE see Thonemann 2011, 293, and on Miletus’s prosperity for much of this period ib. 334–338.
82 Harris 2011a, 116–117.
83 Kaplan et al. 2009.
84 And some historical oddities are perhaps inevitable: ‘Maghreb regions of North Africa
The most striking results of this approach, as far as the period 800 BCE to 700 CE is concerned, are a major reduction in ‘forest coverage on usable land’ between 500 BCE and 1 CE both in North Africa and in a zone designated as central and western Europe, with some recovery by 500 CE, especially in North Africa and the zone designated as ‘eastern regions with consistently low forest cover’. Thus

<table>
<thead>
<tr>
<th></th>
<th>1000 BCE</th>
<th>500 BCE</th>
<th>1 CE</th>
<th>500 CE</th>
<th>1000 CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central and western Europe</td>
<td>77.2</td>
<td>70.6</td>
<td>50.7</td>
<td>52.4</td>
<td>40.2</td>
</tr>
<tr>
<td>North Africa</td>
<td>93.9</td>
<td>75.7</td>
<td>33.3</td>
<td>43.6</td>
<td>27.8</td>
</tr>
<tr>
<td>‘Eastern regions with consistently low forest cover’</td>
<td>48.7</td>
<td>40.4</td>
<td>32.5</td>
<td>41.0</td>
<td>36.5</td>
</tr>
</tbody>
</table>

But there are several serious weaknesses in this approach. One is a vastly oversimplified idea of consumption patterns. Kaplan et al. shunt this problem aside, announcing that they ‘assume that population change is the primary driver of change in forest area for the years 1000 BC to 1850’. Taken literally, this may be true, but their assumption ignores the enormously variable pressures on both timber for fuel and construction-timber within the period in question—just consider the single item of fuel for metallurgy, which I discussed earlier. The second serious weakness in this paper is that its authors hugely overestimate the amount of land necessary for subsistence in a pre-modern economy, by a factor of perhaps five with regard to Mediterranean populations. Their Figure 9, though it offers no speculation about the population density of the Mediterranean world in the period I am discussing here, implies, in conjunction with the rest of the article, that the cultivable land in that region could in antiquity have supported between 10 and 30 people per km$^2$. The origin of this estimate is unclear, but it is generally held, on the basis of extensive research, that one to two hectares per

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$^{85}$ North Africa means for them Morocco, Algeria, Tunisia and Libya; central and western Europe means Czechoslovakia, France, Germany, England-Wales, Ireland, Italy, Poland, Portugal and Spain.

$^{86}$ This means Cyprus, Greece, Iraq, Palestine-Jordan, Syria-Lebanon and Turkey-in-Asia.

$^{87}$ One might quarrel about many details here. For instance, it is not plausible to suppose that the central and western European zone had notably less forest coverage in 1000 CE than in 1 CE (the culprit here is clearly an indefensible ‘progressive’ view of history). Ancient Cyprus was certainly not a region of ‘consistently low forest cover’. And so on.

$^{88}$ Kaplan et al. 2009, 3019.

$^{89}$ Kaplan et al. 3028.
person were sufficient for subsistence, \(^{90}\) i.e. population density on cultivable land lay in the range 50 to 100 persons per km\(^2\). Be it noted that at a density of 20 persons per km\(^2\), the population growth conservatively hypothesized for the Graeco-Roman Mediterranean (see above) would have required the clearance not of 350,000 km\(^2\), but of perhaps 1,750,000 km\(^2\), which is entirely impossible.

These two criticisms of Kaplan et al. might very roughly cancel each other out: they underestimate some of the destructive forces tending to produce deforestation, as far as the Graeco-Roman period is concerned, but they overestimate others. What gets left out, however, is what is culturally specific. This matters in two ways (and raises again the question of definition). No ancient or mediaeval town or city could afford to be reckless about its fuel needs, and as noted above we have every reason to believe that with a few readily comprehensible exceptions ancient communities satisfied those needs within their own territories, which implies that they at worst maintained enough scrub, \textit{boscoaglia}, \textit{phrygana}, and coppiced or pollarded trees to supply themselves with fuel. The need for long timber was not so manageable, or rather what made it manageable was a combination of trading networks and imperial power that left large areas denuded of tall trees over, at least in some cases, long periods. The relative importance of ship-building and on-land building varied greatly from period to period, and the effects of these needs on the landscape must have varied greatly as well. In some cases (fifth- and fourth-century Attica, for instance, and the lower Tiber valley in the high Roman Empire), the effects probably amounted to what by any standards should count as deforestation; in other cases, the effects must have been less drastic, with some tall trees surviving but little in the way of continuous woodland.

I consider therefore that Kaplan et al. probably overestimate to a significant degree the \textit{relative} decline of forest coverage in both central and western Europe and the ‘eastern regions with consistently low forest cover’ in the five centuries from 500 BCE onwards. Their article is undeniably useful, but it merits further discussion not unqualified citation.

\textbf{WOODLAND MANAGEMENT}

The totality of the evidence thus seems to suggest in short that there were probably some deforested areas in classical and Hellenistic Greece and

\(^{90}\) Malanima 2009, 106, with references.
the high Roman Empire. At the height of the Roman Empire, many areas that had been more or less heavily wooded in 800 BCE were farmland with scattered trees, or scrub-land, or in some cases heavily eroded land. Some areas that lost their trees were woodland once again by 700 CE. There was, however, no general crisis of timber-supply in antiquity, not only because woodlands grow again in temperate climates and because demand created trading mechanisms: landowners also put a great deal of effort into looking after what they of course knew to be a valuable resource. Such an assertion does not imply any idealization of the classical world, nor should it obscure the law of unintended ecological consequences (we know, for example, about the ecological harm done by the Roman system of drainage in one section of the valley of the Rhône91).

Our direct evidence about tree- and woodland-care in classical antiquity consists, admittedly, of advice from highly literate arboricultural experts such as Columella whose works cannot have been widely circulated: yet their advice arose ultimately from real experience and can therefore give some hints about actual practice. In real life, no doubt, practical woodsmen mostly passed on information and advice by word of mouth.

You can in fact see knowledge and ambition increasing in the surviving texts. Theophrastus, writing in the late fourth century BCE, is already impressive: consider for example his discussion of the merits and demerits of various kinds of wood for charcoal-making,92 which also seems to reveal the existence of a sophisticated charcoal market. He apparently knew something about coppicing.93 He gives advice about grafting.94 But while he envisages the planting of fruit trees, he clearly sees almost all other trees as simply natural growths; he seems to make an exception for cypresses,95 presumably cultivated for the long timbers they provided for construction and shipbuilding.

150 years later, Cato is several degrees more interested in the cultivation of non-fruit trees; he explains how to plant willows, elms and pine-trees as well as cypresses (to which he too pays special attention).96 There is already a *seminarium*, a nursery, for young olive-trees on his ideal estate,97

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91 Such at any rate is the argument of Van der Leeuw et al. 2005, 25.
93 I take this to be the reference of the word *kolobon* in *Hist. Plant*. 5.9.2.
94 *Caus. Plant*. 1.6, etc. Aristotle knew of this technique.
95 *Hist. Plant*. 2.7.1.
96 *De agr*. 9, 28, 151. See further Meiggs 1982, 262–263. Other references to woodland management include chs. 6, 7, 17, 37 end, 38 end, 55.
97 *De agr*. 45–46.
this was a regular Roman institution. He gives detailed instructions about grafting olives, fig-, pear-, and apple-trees and vines. He recommends the owner of estates that are suburbani to produce firewood for the market (whereas the aim of planting tall trees is not the market but simply self-sufficiency).

By the time we get to Varro, in the 30s BCE, there has been another change: he refers to the Roman habit of planting big trees, specifically pines, cypresses and elms; he particularly recommends the latter—‘there is no better tree for planting; it is extremely profitable’. But why? Not, as we might have expected, because these are three of the four woods most used in ship-building, but for more complex reasons: an elm ‘often supports and gathers a certain number of baskets of grapes, yields most agreeable foliage for sheep and cattle, and provides stakes for fencing, and also for hearth and furnace’. At all events this passage demonstrates that Varro and his readers, who will have included substantial Roman landowners with estates in diverse parts of the Mediterranean, are completely familiar with the techniques necessary for planting such trees.

Columella, like Cato, was a great enthusiast for vineyards, but he admits that there are ‘many’ landowners who preferred pasture land or silva caedu—timber-producing land for coppicing; he shows once again how familiar Roman landowners were with techniques for planting large trees. He also shows that by modern standards Roman landowners coppiced their trees on a very short cycle, a reflection of the powerful demand for wood fuel.

In the same period the elder Pliny maintains that cypress branches, which go for a denarius apiece after twelve years of growth, are the most profitable kind of planting: this is because they can be used as vine-supports. He

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98 De agr. 40–42.
99 De agr. 6 and 7.
100 RR 1.15 (‘maxime fructuosa’, correctly translated by Heurgon 1978 as ‘d’excellent rapport’). Williams 2003, 97, was wholly mistaken to claim that there were no ‘examples of efforts to plant trees other than olive trees’. On Roman perceptions of the relative desirability of woodland and other kinds of land see Giardina 1981, 102–103.
101 Silver-fir would not come into his calculations in any case, since it is assumed that the ideal estate is not at a very great altitude.
102 De Re Rustica 3.3.1.
103 De Re Rustica 5.6 and De arboribus (though the latter concerns fruit-trees, and the author says at the beginning [1.1] that trees that provide materia, construction timber, grow without human aid).
104 See Meiggs 1982, 268.
105 NH 16.141. They are known as ‘a daughter’s dowry’, he says, twelve being his idea of the age at which a girl would marry.
takes it for granted that many different varieties of trees other than fruit trees are regularly propagated by landowners.\textsuperscript{106}

Trees for coppicing, in addition to those which we have mentioned [willow, chestnut, \textit{aesculus} oak and cypress] are the ash, laurel, peach, hazel, and apple, but these shoot more slowly and when fixed in the ground tolerate the soil, not to mention the damp, with difficulty. The elder, on the contrary, which is very strong timber for a vine-stake, is grown from cuttings like the poplar.

Other species of non-fruit trees deemed worthy of cultivation include plane, elm, ash and alder.\textsuperscript{107}

In short there is every reason to think that by the second century BCE and even more in later times Roman estate-owners regarded many species of tree as useful assets, to be exploited and therefore to be propagated.

\section*{The Impact of Climate Change}

In the temperate zone that makes up the majority of the area under discussion, the most important climatic factor that may have affected the lives of trees is the pattern of precipitation, and not only its volume but its seasonal distribution.\textsuperscript{108} Can we identify any Mediterranean climate changes in the period 800 BCE to 700 CE that are likely to have had large effects on woodland, and in particular any changes in patterns of rain- and snow-fall? The sheer diversity of Mediterranean climates\textsuperscript{109} is bound to make this difficult.

The papers by Michael McCormick and Sturt Manning in this volume both review the existing evidence. My reading of their work and of the work they cite is that as far as archaic Greece is concerned (the eighth and seventh centuries BCE in particular), while it is very possible that precipitation increased and aridity declined across wide areas of the eastern Mediterranean, it is too early to assert this as a fact.\textsuperscript{110} Even if it were true, it is quite uncertain what the net effects on woodlands would have been,

\footnotesize
106 \textit{NH} 17.151.

107 \textit{NH} 17.65–78.


109 Cf. Grove and Rackham 2001, 25, who do not even consider the eastern or southern shores.

110 A recent review of the literature on Holocene climate in the eastern Mediterranean, which considered some eighty studies, concluded that ‘during the late Mid-Holocene (2800–1800 yrs BP) diverging records prevent the emergence of a coherent picture’ (Finné et al. 2011, 3167). (BP for these authors means before 1950). There is still a chronic shortage of data with high-enough chronological resolution to be useful to a historian.
since the hypothetical change in climate may have been a prime cause of the demographic expansion that undoubtedly took place in this period, at least among the Greeks (shades of Malthus). Greeks of this period greatly increased their production of both metal artefacts and ships. A modest increase in precipitation may perhaps have caused more loss of woodland than gain. It is a matter of scale, and we need more numbers.

We seem to be on more solid ground in the third century CE and later. McCormick’s group considers that precipitation declined in Rome’s eastern provinces and in north-eastern Gaul in the third century and recovered in the fourth. Another dry period sets in in north-eastern France about 450 and continues for about two centuries. In the eastern provinces, according to this group, a humid climate continues until ‘it changes dramatically in the sixth century’. These changes coincide to some extent with the pollen evidence reviewed earlier (but they appear to be partly based on the pollen evidence). The most serious difficulty is that north-eastern France is merely a fragment of the area we are trying to generalize about, while the eastern provinces of the Roman Empire cover a huge and ecologically diverse area where we would need data from many different places. And a recent literature review seems to show that the eastern-Mediterranean climate grew wetter not drier from 550 to 750 CE.

Conclusions

Much woodland was degraded or disappeared in the Graeco-Roman Mediterranean. But no extreme hypothesis about deforestation seems well-founded, and there is no reason to believe in a generalized crisis (though Italian wood being used for fuel in Egypt comes close to suggesting that). In truth, the uncertainties and unknowns are very extensive. Both scientists and historians should work harder to achieve a clearer definition of deforestation, or a typology of deforestations. And, the problem of generalization is fundamental: we need more discussion of, on the one hand,

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111 Büntgen et al. 2011; McCormick, this volume, p. 70.
112 Ibid.
113 McCormick, this volume, p. 71.
114 Finné et al. 2011 (see above, n. 110), 3168 (‘a widespread period of wetter conditions at 1400–1200 yrs BP’). See their Fig. 1. Their ‘eastern Mediterranean’ includes Italy, and they have no data from Syria or Egypt. More precipitation from 550 CE onwards at a site in Switzerland: Roos-Barraclough et al. 2004.
115 It is depressing to read an account by a classicist who, while citing some scientific studies in his bibliography, makes no systematic use of them (Thommen 2012, 37–41, 85–89).
the representativeness of the scientific evidence and on the other the real value of the textual sources.

Thus the following claims are tentative:

(1) Classical Greek deforestation, in a weak sense of the term (land clearance, with some trees left behind) was widespread, but in a strong sense of the term it was probably restricted to Attica and the immediate supply area of a few other cities. Local fuel crises probably occurred wherever metal-smelting was intense (so for this reason too Attica was under pressure in the fifth and fourth centuries).

(2) Hellenistic and Roman demand intensified in the third century BCE. This demand was met to some extent by a stronger trading network and more careful woodland management, but ship-building and fuel-needs are likely to have deforested some areas quite seriously—most of all perhaps in Italy—, and left others with much less woodland coverage.

(3) Stress on woodland resources continued to mount all the way through the high-imperial period of prosperity, perhaps down to Severan times.

(4) Alleviation that came later was highly selective. Some areas regained woodland, but whatever the reasons were (unfavourable climate change, poorer management) others did not.
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