Supplementary Material

8
FOOD PRODUCTION
(Expanded Version)

Geoffrey Kron

INTRODUCTION

Although it would be attractive to offer a survey of agriculture throughout the ancient Mediterranean, the Near East, and those regions of temperate Europe, which were eventually incorporated into the Roman empire, I intend to concentrate primarily upon the best attested and most productive farming regime, that of Augustan Italy,[1] which was broadly comparable in its high level of intensification and agronomic sophistication with that of Greece, Western Asia Minor, North Africa, Baetica and Eastern Tarraconensis. Within the highly urbanized and affluent heartland of the Roman empire, our sources and archaeological evidence present a coherent picture of market-oriented intensive mixed farming, viticulture, arboriculture and market gardening, comparable, and often superior, in its productivity and agronomic expertise to the best agricultural practice of England, the Low Countries, France (wine), and Northern Italy in the mid 19th century. Greco-Roman farmers supplied a large urban population equal to, if not significantly greater than, that of early 19th century Italy and Greece, with a diet rich, not just in cereals, but in meat, wine, olive oil, fish, condiments, fresh fruit and vegetables. Anthropometric evidence of mean heights, derived from skeletal remains, reveal that protein and calorie malnutrition, caused by an insufficient diet based overwhelmingly on cereals, was very acute throughout 18th and 19th century Western Europe, and drove the mean heights of the Spaniards, Italians, and Austro-Hungarians as low as 158-162 cm, comparable to the heights of poor peasants in the Egyptian Old Kingdom. The evidence from Roman Italy, on the other hand, allows us to estimate a mean height of 168cm, equal to that of Italian males just after World War II, and the few figures from Hellenistic Greece suggests a mean height of 172cm, a level not reached in modern Greece until the late 1970s, providing ample confirmation of the success of Greco-Roman agriculture in feeding a large, highly urbanized population to a very high standard.[2]

Such high productivity can present a challenge for farmers, however, the problem of possible overproduction. As the Roman agronomists were acutely aware, low prices and insufficient demand were always a potential constraint on the profitability of intensive farming, and many farmers, particularly in mountainous regions isolated from lucrative urban markets, although fully capable of achieving high yields, wisely chose to

[1] I do not propose to offer a descriptive account of Greco-Roman farming here. We have excellent syntheses of the ancient literary evidence in White 1970; Flach 1990; Sirago 1995; Marcone 1997; and in Marcone and Forni 2002, and of the archaeozoological and literary evidence in Peters 1998 and MacKinnon 2004. Instead, I follow Pleket 1990 in focusing on productivity and the relationship between Greco-Roman and early Modern farming systems.

[2] Kron 2005a. [For a different reading of the Roman evidence, see Chapter 15. (Ed.)]

use more extensive methods, or specialized in cattle ranching,[3] or in those crops, which were easily transported to distant markets. Even in the Mediterranean core of the empire, therefore, extensive farming will have been relatively common, although advances in Hellenistic, Carthaginian and Roman agronomy will have helped boost the productivity and lower the costs of extensive farming and ranching as well, by introducing new cultivars of grapevine, olive, fruit and nut trees, as discussed below, as well as better forage and green manure crops,[4] and improved grazing management.[5] Moreover, although we cannot discuss the issue in detail here, it is likely that the provinces of Britain, Gaul, Germany, Moesia, Pannonia, and even Egypt and Palestine, lagged somewhat in incorporating the model of intensive mixed farming we find in Roman Italy, more as a result of low levels of urbanization, cultural conservatism or the effects of persistent social inequality and low demand, however, rather than an unwillingness to learn new agronomic techniques.[6]

TECHNIQUES, AGRONOMIC EXPERTISE, AND PRODUCTIVITY

The most important and informative sources for ancient agriculture, despite the objections raised, mistakenly in my view,[7] about their applicability to the farming of ordinary owner-occupiers, are the great Roman agronomists, Cato, Varro, Columella, and Palladius. Their rich storehouse of agricultural expertise, and that of many lost works, was kept alive by the Arab agronomists of al-Andalus, culminating in the work of Ibn al-Awwâm.[8] In the rest of Europe, they were constantly reprinted, admired, and studied from the moment urban life and intensive agriculture began to revive in 13th century Italy, as reflected in Palladius' influence on Pier de Crescenzi,[9] until the middle of the 19th century, when Liebig's systematic application of the science of chemistry, and Lawes' experiments at Rothamsted farm inspired a new scientific agronomy.[10] The soundness of their advice is constantly emphasized by those with comparable experience in organic farming,[11] most notably, perhaps, in the comprehensive and insightful two volume study of Adam Dickson, arguing for the superiority of Roman practice to that of

[3] See Pasquinucci 2002.
[4] Kron 2004b: 275-304.
[5] Kron 2004b: 311-6.
[6] For the agriculture of the Roman provinces, see the excellent overview in Marcone 1997: 175-203. For Romano-British and Gallo-Roman farming, see Reynolds 1979; 1995; Jones 1981; 1989; Ferdière 2006; Margaritis and Jones 2008. For Palestine, see especially Safrai 1994; and for Egypt, see Schnebel 1925; Rathbone 1991; Kehoe 1992; Rowlandson 1996; Bowman and Rogan 1999; Banaji 2001; Manning 2003; Brun 2004b: 143-50; 169-83; Moreno Garcia 2005; Rathbone 2007: 700-5; Bowman 2009.
[7] For the high productivity and continued vitality of peasant farming in Roman Italy, with ample discussion of the unfairness of the stereotype of the ignorant or conservative peasant, see Kron 2008b. See also, for example, Lo Cascio 2009a: 91-135; Cifani 2009; Carandini 2009. For Greece, see Hanson 1999.
[8] Ibn al-'Awwâm 2000. Compare Marcone 1997: 206.
[9] Ambrosoli 1983.
[10] White 1970: 14-43; Martin 1971; Amouretti 1981; Marcone 1997, 206-17; Fussell 1972; Ambrosoli 1997; Santini 2002. For the first attempts at scientific studies of plant nutrition, manuring and yields, and the controversies engendered, see Hall 1908; Russell 1942; Werner and Holmes 2002.
[11] See Fussell 1972 and Ambrosoli 1997 for references.

England in the midst of its agricultural revolution,[12] and in many of the best recent accounts.[13]

The loss of the extensive agronomic literature of the Greeks and Carthaginians,[14] so admired by the Roman agronomists,[15] which was specialized enough to boast entire books devoted to alfalfa and the medics,[16] or the radish,[17] is a profound problem for our understanding of Greek agriculture, although outstanding work has been done by scholars such as Hodkinson and Amigues to extract information from scientific works, particularly Theophrastus.[18] We will therefore concentrate our attention upon Roman farming, although it is likely that Classical and Hellenistic Greek farming was at least as intensive and productive as that of Augustan Italy, leaving aside the Romans' development of mariculture in hydraulic concrete fishtanks, or their introduction of new fruits, vegetables, or grapevine cultivars as the result of conquest and expanded trade.

The absence of agronomic sources, and insufficient attention to the extant Roman agronomists, helps to explain the persistence, alongside more realistic assessments,[19] of a still influential primitivist school of Greek agriculture,[20] but an even more significant problem comes from the use of deceptive ethnoarchaeological parallels from modern Greece.[21] The extreme poverty and low productivity of modern Greek agriculture is often assumed to be the inevitable result of environmental constraints,[22] rather than the result of social and historical factors which undermined agriculture, including rural depopulation,[23] poor access to urban markets,[24] and competition from more intensive agricultural regimes.[25] For the few isolated villages of peasant farmers in Greece under the Venetians, Ottomans, and into the modern era, there was little incentive to increase productivity, and only the simplest cost- and labour-saving methods of farming were used. Much of the arable land was simply abandoned. In the 19th and early 20th century, the plain of Troezen was "uncultivated and full of scrub except for the lemon

[12] Dickson 1788. For the importance of Dickson's analysis and comparative perspective, see Carandini 1982; Marcone 1997: 217-8.
[13] Note in particular Billiard 1913; White 1970; Peters 1998. See also Magerstedt 1859; Magerstedt 1862; Gummerus 1906; Forni and Marcone 2002; Diederich 2007: 10-105.
[14] Oder 1890-93 is still the most comprehensive treatment. For Carthaginian agronomy see van Dommelen and Gómez Bellard, eds. 2008: 22-8. Krings' treatment is unduly skeptical, however.
[15] Despite his notorious anti-Greek bias and the rather traditional approach evident in his work on agriculture, even Cato betrays a strong influence. See Boscherini 1970: 22-91.
[16] Pliny, *NH* 13.130.
[17] Pliny, *NH* 19.87.
[18] See, for example, Hodkinson 1988; Amigues 2007.
[19] Amouretti 1986; Osborne 1987; Hodkinson 1988; 1992a; 1992b; 2000; Lohmann 1992; 1993; Burford 1993; Hanson 1999; Garnsey 1998; Roy 1999; Chandezon 2003; Howe 2008.
[20] Jardé 1925; Gallant 1991; Isager and Skydsgaard 1992; Foxhall 2007; Foxhall et al. 2007; Moreno 2007: 37-76. See also Davies 2007: 339-52 for a detailed recent discussion.
[21] See the judicious cautionary remarks of Forbes 1992.
[22] See Semple 1922; Pepelasis and Thompson 1960. For the weakness of this explanation of the under-development of the Italian Mezzogiorno, see Kron 2004a.
[23] See in particular Forbes 2007, and contrast Hansen 2006. Note Bintliff 2007 for a corrective against the impression of unrelieved collapse, however.
[24] Despite energetic attempts of the peasants in modern Greek villages to find any possible niche to allow them to market their agricultural produce or rural crafts. See Lee 2001; Forbes 2000: 47-8.
[25] Doukas 1945; Margaropoulos 1952; May 1953; MacDonald and Rapp 1972: 47-80; Renfrew and Wagstaff 1982; Mee and Forbes 1997; Wagstaff 2002.

orchards and other crops near the village of Troizin and the gardens around the estates of villa owners."[26] Olive trees were planted in large numbers, when trade outlets opened up,[27] but in the Southern Argolid under Venetian rule there were barely 1.3% as many olive trees as one finds today,[28] or, in all likelihood, in antiquity,[29] and they received relatively little of the trenching, manuring, or irrigation[30] recommended by Theophrastus and the Roman agronomists to boost their yield.[31] As late as 1960, only 10% of agricultural land in Greece received any artificial fertilizer whatsoever, and only 3.7% received any manure,[32] a stark contrast from the intensive manuring described by the ancient texts and confirmed by survey archaeology.[33] Animal husbandry was restricted to rough grazing of sheep and goats,[34] with mules or donkeys used to pull ploughs and thresh grain,[35] rather than the oxen still used in the Byzantine era.[36] In the Classical and Hellenistic period, however, Greece, Sicily and Southern Italy was renowned for its intensive animal husbandry, and livestock renowned for their size, fertility, and fine wool, were bred on a large scale.[37]

The best informed authorities have long acknowledged that Roman farming was both sophisticated and productive,[38] with clear evidence that the ancients had anticipated the critical innovations most responsible for the modern agricultural revolution: seed selection; effective tillage; hoeing and harrowing to destroy weeds; crop rotations; the suppression of bare fallow; the rotation of legumes, whether for human consumption, fodder or green manure; irrigation, particularly of meadows and garden vegetables; artificial leys sown with leguminous fodder crops; housing of livestock; improved manure management; careful grazing management for range and pasture land; and, most decisively, as I have argued in a number of publications, ley farming or convertible husbandry, still the most effective system of intensive mixed farming.[39]

---

[26] Clark 2000: 174. For the challenges of the Greek agrarian economy under Venetian and Ottoman rule, see the essays in Davis and Davies 2007.
[27] Forbes 2000: 42.
[28] Forbes 2000: 65 table 3.8.
[29] See Brun 2004a: 84-129; Lohmann 1993: 194-219; Hanson 1999: 33-5; 78-84.
[30] See, for example, MacDonald and Rapp 1972: 53-5.
[31] Brun 2003: 130-5; Foxhall 2007: 97-129.
[32] Pepelasis and Thopmson 1960: 149.
[33] Hodkinson 1988; Bintliff and Snodgrass 1988.
[34] Margaropoulos 1952. Devastating erosion occurred in the mid-20th century, once flock sizes began to increase, although the long-term effect is often exaggerated. See Rackham 1983; 1996.
[35] Clark 2000: 176-7.
[36] Teall 1971; Laiou-Thomadakis 1977. For the role of the Peloponnese as an exporter of cattle in the 18th century, see Forbes 2000: 43.
[37] Magerstedt 1859: *passim*; Rosivach 1994; Hodkinson 1988; Roy 1999: 329-34; Chandezon 2003; Howe 2008: 58-65; Kron 2004a; Kron 2008a: 175-6. As Howe 2008: 31 notes, Aristotle describes animal husbandry as the most profitable branch of farming (*Pol*. 1258b12-21). Note that cattle were raised for export in the Peloponnese as late as the 18th century (Forbes 2000: 43; 57-61).
[38] See, e.g., Dickson 1788; Daubeny 1857; Magerstedt 1859; 1862; Gummerus 1906; Billiard 1913; Day 1932; Ghigi 1939; White 1970a; 1970b; Kolendo 1980; Capogrossi Colognesi 1982; Carandini 1988; Pleket 1990; Pleket 1993; Forni 1994; 2006; Marcone 1997; 2006; Forni and Marcone 2002; Hitchner 2002; 2005.
[39] White 1970: 110-40; 202; Carandini 1985; 1988; Sallares 1991; Kron 2000; 2005c; 2008a; 2008b: 73-5 with further references. See Grey 2007: 366-7 for the continued role of ley farming in late antiquity. We have some circumstantial archaeobotanical evidence for convertible husbandry in the presence of weeds associated with cereal cultivation in meadow hay from Pompeii. See Ciaraldi 2007: 84-5; 158-9. For the

Of all these innovations, the most significant were those which allowed farmers to keep more livestock, not only for the great profits to be made from their sale,[40] but because, properly managed, their manure was the cheapest and most beneficial source of nitrogen, which is the critical limiting factor in the yields of most crops.[41] Until very recently, historians of ancient farming have ignored the most valuable index of the productivity of Greco-Roman animal husbandry, and of their entire regime of intensive mixed farming. As studies of livestock bones demonstrate, Classical Greek and Roman cattle were dramatically larger than those of the Bronze and Iron Age, and of the Medieval period, with cattle standing 20 cm taller at the withers and weighing almost twice as much, and sheep were bred as large as modern animals, with wool as fine as the Merino.[42] As late as the 1880s, cattle of comparable size could be found only in England, Holland, and in a few scattered regions of advanced farming.[43] The nutritional needs of such large animals are such that their presence in large numbers is probably reliable evidence of the application of convertible husbandry or, at the very least, of improved pastures, meadows, and leguminous fodder crops.[44] Although the smaller Celtic breeds remained dominant in Roman Britain, throughout most of Gaul and occupied Germany, improved Greco-Roman cattle had almost entirely supplanted the older breeds by the fourth century AD.[45] Of course, some unimproved sheep breeds continued in widespread use, since they were inexpensive and hardy producers of generalized medium wool for coarse clothing, and some smaller cattle breeds were retained as prime milk producers, so improved methods of husbandry may well have been applied on many sites with smaller livestock.

Not only did the Romans raise large livestock more consistently and over a broader geographical range than 19th century Europeans, their use of fodder crops was arguably equal, if not superior, even to that of England and the Netherlands. Alfalfa, which the ancients, like modern agronomists, recognized as the world's single best forage crop, had almost entirely disappeared from cultivation through the Middle Ages, outside of Arab Spain and Provence, and its culture only spread very gradually into the rest of Europe when the texts of the Roman agronomists, widely published from the Renaissance on, were painstakingly re-intepreted, as detailed in a classic work by Ambrosoli.[46] In addition to alfalfa and most of the principal modern fodder crops, the ancients added a number of outstanding, but still little-known, fodder crops, such as subterranean clover, rediscovered in 20th century California and Australia as a prime drought-resistant forage crop for seeding in grasslands, and shrub trefoil (*Medicago arborea*) a hardy drought-

---

role of such innovations in the English agricultural revolution, see Kerridge 1967; Campbell 2000: 10-16; Allen 2008.

[40] As Caird 1852: 475-6 noted, most of the growth in 19th century British farm incomes came from livestock rather than cereal prices, which remained stagnant. For the profits of the trade in meat in Roman Italy, see below.

[41] As argued recently, in considerable detail, by Allen 2008.

[42] See, e.g., Lepetz 1996; Peters 1998; Kron 2002; 2008a; 2008b: 74-6.

[43] See Kron 2008b: 75.

[44] See Kron 2004a; Ciaraldi 2007: 75-85.

[45] See Peters 1998: 56 table 6.

[46] Ambrosoli 1997. *Pace* Ciaraldi 2007: 84, but alfalfa was utilized in the West long before the extant Roman agronomists highlighted its importance. For recent identifications of alfalfa from 4th century Provence and Metapontum, see Buxó et al. 2003; Carter 2006.

resistant shrub version of alfalfa, ideal for ovicaprines, particularly in semi-arid conditions.[47]

The thorough integration of livestock into arable farming fostered heavy manuring and high yields. As was recognized long ago by Dickson,[48] Roman techniques for managing compost and manure were sophisticated,[49] dressing the land more heavily and protecting the value of manure more carefully than English farmers at the end of the 18th century.[50] In addition to farmyard manure and compost, we have evidence for the use, often extensive, of manures imported onto the farm, including nightsoil, potash and wood ash, bone, and marling with chalk or calcium carbonate.[51] Modern artificial fertilizers of a sort unknown to the Romans were only manufactured in England beginning in the 1850s,[52] and did not became an important factor in arable farming until the 20th century, particularly in North America and the Soviet Union, as a result of the introduction of tractors and combine harvesters.[53] Intensive mixed farming is still much more productive, however, (Holland boasted 542 cattle per square kilometer in the mid 20th century compared to 132 for Europe as a whole, and 58.3 for the USA[54]), and the divorce of arable farming and animal husbandry can cause severe and expensive environmental problems from pollution or the failure to replenish organic matter in the topsoil, and is extremely wasteful of energy and of manure, which is not only rich in nitrogen, but also phosphorus, potassium, trace elements, soil-fertilizing bacteria, and especially humus.[55]

Unlike the high productivity of animal husbandry, which can be demonstrated archaeologically, direct evidence of ancient yields must rely on literary evidence. As recent analyses by Spurr, Erdkamp, and Goodchild demonstrate, comparing ancient wheat yields with those attested in Medieval and Early Modern Europe,[56] the Romans could match the productivity of the most intensive Medieval or Modern agriculture, or that of Italy as a whole in the 1970s.[57] Columella's claim that four-fold cereal yields were now common over a "great part" of Italy should be interpreted carefully. Columella

[47] Kron 2004b; Ciaraldi 2007: 75-85.

[48] Dickson 1788: 1: 253; 273; 281-2; 289-90; 299-301. Dickson also notes the use of green manure. See Dickson 1788: 1: 302.

[49] See White 1970: 125-45, noting especially the knowledge of the relative value of different livestock species as fertilizer; Billiard 1913: 122; Fussell 1971: *passim*; Applebaum 1975; Spurr 1986: 128-31; Favory et al. 1994: 180-99; Marcone 1997: 64-7; Miller and Gleason 2002: 38-9; Kron 2005c: 293-6; 2008b: 76.

[50] See references in Dickson 1788, cited above, and in Kron 2008b: 276 note 30, comparing the Roman agronomists' recommendations with intensive farming in the Netherlands and England.

[51] Pliny, *NH* 17.50; Col. 2.14.5; Pallad. 10.3.2. The fullest account is in Fussell 1971. See also, more broadly, Hall 1908; Miller and Gleason 2002: 25-43. For marling see Russell 1942.

[52] Hall 1908; Russell 1942.

[53] See Warringer 1939: 117. The productivity gains were generally modest, except for the largest farms. See Warringer 1939: 7-10. For the devastating environmental effects of the introduction of mechanized agriculture using extensive management in the American Midwest, see Sylvester 2009.

[54] See Kron 2004a: 121 table 1.

[55] Kron 2008b: 76 note 34; Robertson and Vitousek 2009: 102. For the environmental advantages of Roman intensive mixed farming, see Kron 2005c.

[56] Spurr 1986: 82-8; Erdkamp 2005: 34-46; Goodchild 2007: 246-97; 414-8. Note also Pritchard 1972 arguing that yields of 10-fold or greater can be inferred from Cicero's testimony for Sicily as a whole.

[57] As Goodchild 2007: 337 points out, using FAOSTAT statistics, Italy's wheat yields in 1970 were 13:1, comparable to the 15:1 which Varro asserts for Etruria, for example.

regards such yields as derisorily low, but they are precisely what one would expect in extensive farming without adequate manuring, fallowing or weeding, and significantly lower yields were normal from the Medieval period through the 19th century.[58] Since Columella's claim is part of a less than fair or candid argument for the profitability of viticulture,[59] one is tempted to dismiss it, but given the vast imports of inexpensive wheat from Sicily, North Africa, and Egypt, it would not be surprising if many farmers reserved their labour and manure for more lucrative crops.

The most striking evidence of high yields comes from viticulture, a particularly demanding branch of intensive farming. Tchernia's comparison of the productivity of recent and historical vineyards with the yields expected by the Roman agronomists for well-managed vineyards, show that the Romans were able to match the performance of their counterparts in 19th or even 20th century France. Columella's benchmark for the minimum production of a well-cultivated vineyard, 21 hl/ha, is almost exactly the same as the average productivity of 19th century France, and his estimate of a normal yield of 31.5 to 42 hl/ha matches French figures for the early 1950s.[60] Some scholars question whether ancient vintners could match modern yields, but many modern vineyards using traditional techniques are very competitive, and the Roman agronomists reflected a long tradition of competence and expertise, as Billiard demonstrates in detail in a classic work, based on a deep knowledge of the best French oenology at the turn of the 20th century.[61] In fact, as Billiard noted,[62] the Romans kept sheep or other livestock on their farms, allowing them to manure their vineyards, whereas their French counterparts generally had to purchase manure, or, as Lachiver points out,[63] declined to fertilize their vines altogether. It is therefore not surprising that French yields did not match the benchmarks of the Roman agronomists until after World War II, when winemakers began fertilizing their vineyards in earnest.[64]

THE INFLUENCE OF COMMERCIALIZATION, URBAN MARKETS, AND TRADE

The intensification of Greco-Roman agriculture depended upon the existence of prosperous urban mass markets for agricultural produce, integrated by vigorous trade networks. As Pleket's magisterial comparative survey reminds us,[65] in *ancien régime* Europe, a system of intensive agriculture specializing in the production of more

[58] In addition to the work of Spurr, Erdkamp and Goodchild cited above, note Campbell 2000: 320-2, which noted that five-fold yields were expected by optimistic Medieval English agronomists, but that yields above 3 or 4:1 were uncommon in actual farming.
[59] See especially Billiard 1913: 112-47, and Dumont 2000 with bibliography.
[60] Tchernia 1986: 359-60; cf. Lachiver 1988: 393-4. Columella's estimate of a good yield, at 63 hl/ha is just short of contemporary French yields, which hover around 70 hl/ha. Estimates of the yields of Egyptian vineyards based on papyrological evidence are rather lower than those suggested for Roman Italy, as one would expect, ranging from 12-25 hl/ha up to 35 to 37 hl/ha (Brun 2004b: 148), but these figures still match or exceed the average yield for France at the end of the 19th century, which averaged 20 hl/ha.
[61] Billiard 1913: *passim*.
[62] Billiard 1913: 122.
[63] Lachiver 1988: 178; 184.
[64] Lachiver 1988: 393-4; 516-7; 556-9.
[65] Pleket 1990.

expensive and profitable crops such as meat, cheese, fresh fruits and vegetables, wine, was well established in the highly urbanized trading states of Northern Italy and the Low Countries over the course of the later Middle Ages, with important pockets of development around Paris and London,[66] but much lower standards of farming were normal where the bulk of the population remained overwhelmingly rural and poor: landless labourers, as in much of England or Southern Italy in the 18th and 19th century, or peasants struggling under the burden of heavy rents, taxes, feudal dues, bans, and corvées, as in pre-revolutionary France.[67]

The city-state cultures of Greece, Roman Italy and Carthage were as highly urbanized as the Dutch or Northern Italian city-states, but the level of urbanization was more consistent,[68] and combined with a much more vigorous tradition of democratic politics, and consequently, a higher level of social equality.[69] The effect on agricultural productivity was powerful. The affluence of ordinary citizens,[70] and the policies of their broadly democratic governments, encouraging the large-scale import and distribution of cheap staple foods to the population,[71] freed up income among ordinary people for the purchase of what in many other cultures would be considered luxury foods.[72] This encouraged the sort of agricultural intensification one can see in 16th century Holland, permitting greater livestock production and the sort of intensive mixed farming critical to improved agricultural productivity.[73] The Greek and Roman diet was therefore much richer and more diverse, not just in cereals and legumes,[74] but in meat, fish, shellfish,

[66] Further references in Kron 2008b: 98.

[67] For the low living standards of the working population of Western Europe over the course of the 18th and early 19th century, see the essays in Allen, Bengtsson and Dribe 2005. The low levels of urbanization outside of London, Paris, the Low Countries, and Northern Italy before 1800 is very clear from de Vries 1984. For the critical impact of low levels of urbanization and demand, and of poverty, as brakes on agricultural intensification, see Slicher Van Bath 1963, *passim*; Campbell 2000: 424-440.

[68] See, e.g., Pöhlmann 1884; Jongman 1988: 65-7; 108-12; Bintliff 1997; Hansen 2006: 18-21, estimating that nearly 50% of the Greek population lived in cities or towns; Bintliff 2006: 22, offering an even higher estimate of 75 or 80%; and Lo Cascio 2009b. Even Roman Egypt, traditionally a rural agrarian society, and still unevenly urbanized in the Ptolemaic period, seems to have achieved a fairly high urbanization rate of 20-30%. See Tacoma 2006; Rathbone 2010: For a convincing analysis of the powerful dampening effect of low levels of urban development on intensive farming in Medieval England, even in the region of London, see Campbell 2000: 424-30. See Provost 1993: 219-37; Woolf 1998: 135-40; Bintliff 2008 for the contrast between the high urban density in Greece, Italy and Southern Spain and the very different development in Gaul and Germany.

[69] I plan to discuss this in greater detail elsewhere, but see Kron 2005a; 2008b: 79-86 with further references.

[70] Note, most recently, Woolf 1998: 181-205; Ward-Perkins 2005; Rauh 2005; Wilson 2008b; Wallace-Hadrill 2008; Silver 2009, for the widespread consumption of mass-produced goods, traded through much of the Roman empire.

[71] See, most recently, Erdkamp 2005: 258-316, with references.

[72] See Kron forthcoming and the remarks in Kron 2005a; 2008a; 2008b. The varied diet and presence of meat, fish, fruit, nuts and vegetables of the quarry workers sketched by Van der Veen 1998a is particularly important, since the population consisted solely of labourers, legionaries, and a single centurion. We can therefore rule out the habitual claim regarding food remains at legionary camps, that the expensive foods were the officers'.

[73] See Kron 2000; 2002; 2008b: 79-86.

[74] Spurr 1986: 103-17; Garcia Soler 2001: 66-99; Thurmond 2006: 170-3.

wine, olive oil, condiments, fruit, nuts and vegetables,[75] than that of the rural poor and working classes of 18th and 19th century Europe.[76] Wine, which we shall discuss in some depth, was the object of a true mass market,[77] and there is even less doubt that the same was true for olive oil. The unique dump of millions of Baetican Dressel 20 olive oil amphoras at Monte Testaccio[78] shows that the state distribution of olive oil in the city of Rome, which is unlikely to have represented the whole of the market, would imply per capita consumption at twice the level of early 20th century Italy.[79] Yet, although ancient historians often assume that olive oil has always been a staple of the Mediterranean diet, production on the scale so well attested in the ancient world[80] is largely a phenomenon of the 20th century.[81]

Rome was the wealthiest and most important urban market in the pre-industrial world, and the demand it created for agricultural produce is evident not just from the *annona*, but from Rome's *suburbium*, packed with a dense network of villas and *horti*,[82] famous for many distinct specialties of produce.[83] But Rome was hardly the only megalopolis of the empire, and would have represented only a modest proportion of the overall market for agricultural produce. Trade, cultural contact, and conquest linked the Mediterranean *koine* of Greek, Etruscan, Roman, and Carthaginian cultures with the civilizations of the Celts and Germans, the Near East, Africa, India, and even China.[84] As Pliny declared:

> "For who would not admit, that now that intercommunication has been established throughout the world by the majesty of the Roman Empire, life has been advanced by the interchange of commodities and by partnership in the blessings of peace, and that even things that had lain concealed have all now been established in general use."[85]

[75] For the Greco-Roman diet: André 1961; Brothwell and Brothwell 1969; Dalby 1996; Garcia Soler 2001; Dalby 2003; Cool 2006.
[76] See, for example, Kron 2008b: 81-5; Oddy 1970; Burnett 1979.
[77] Tchernia 1986: 21-7; 58-60; 172-9.
[78] Rodriguez Almeida 1984; Blazquez 1992; Remesal Rodriguez 1998; Remesal Rodriguez 1999; Remesal Rodriguez 2001; Panella 2001: 178-9; Étienne and Mayet 2004.
[79] See Kron 2008b: 86 comparing Hesnard's estimate with modern consumption.
[80] Brun 1996; 2003; 2004a; 2004b; 2005; Bonifay 2004: 477-86.
[81] See, e.g., Halstead 1997: 243-4 and Forbes 2000: 65 table 3.8, which shows only 8,950 olive trees in a region of the Southern Argolid in the late 17th century compared to 658,000 in late 20th century.
[82] For the agricultural wealth of the *suburbium*, see Quilici-Gigli 1979; 1994; Carandini 1988: 339-57; Kolendo 1993; Purcell 1987; 1995; Rossi 1994; Morley 1996; Goodchild 2007; Wilson 2009a; Carandini 2009. For the density of settlement, see the references in Quilici-Gigli 1994; with Pergola et al. 2003; Santillo Frizell and Klynne 2005; Witcher 2005; Frass 2006: 163-73; 205-356; Witcher 2006; 2008; Jolivet et al. 2009. For the Tiber valley survey project, see also Patterson and Millett 1998; Patterson et al. 2000.
[83] Dalby 2000a: *passim*.
[84] For trade, the bibliography is too great to list here, but see, e.g., Rougé 1966; Begley and de Puma 1991; Horden and Purcell 2000; Young 2001; Cappers 2006; Wilson 2009b. For the extensive literature on Greco-Roman 'luxury' foods, see Papathomas 2006: 193 note 3. For the widespread consumption of mass-produced goods distributed through much of the Roman Empire as a result of trade, see Raepsaet 1987; Woolf 1998: 181-205; Ward-Perkins 2005; Wilson 2008b; Wallace-Hadrill 2008; Silver 2009.
[85] Pliny, *NH* 14.3. Compare Aristid. *Or*. 26.9-13.

The trade in condiments and spices, many of which had to be imported from the Near East, Arabia, India and East Asia,[86] confirms Pliny's boast. Despite the fragmentary nature of our sources, 142 different spices and condiments are listed in ancient texts, 84 of which can now be identified.[87] Miller argues convincingly that ordinary Romans were eager to incorporate new condiments and spices into their diets from a relatively early stage, noting the fake spice names incorporated into Plautus' comedies,[88] and the discovery of the monsoon winds led to a dramatic expansion of these imports and a reduction in their cost.[89] The House of Hercules' Wedding at Pompeii provided proof that pepper, oregano, rosemary, bay leaves, fennel, coriander, and capers were consumed,[90] and the desert climate of Mons Claudianus offers an even longer list, which is notable because, with the exception of a single centurion, it was populated entirely by common labourers and a small detachment of legionaries, and all of the food had to be grown on site or hauled into the mountains.[91]

One of the most expensive of the exotic spices, black pepper, was imported in massive quantities. Pliny puts the empire's annual imports of pepper at fifty million sesterces,[92] clear evidence, despite its cost,[93] of an impressively broad market, as is Domitian's dedication of an entire warehouse to stockpile it in Rome.[94] The importance of pepper in Roman cooking is attested by 482 citations in the ancient literature, rivaled only by garum,[95] and it is has been found in large quantities at the Red Sea port of Berenike,[96] and, perhaps more surprisingly, at the German river port of Straubing, on the Danube,[97] and was consumed by the labourers at Mons Claudianus.[98]

A look at the Roman wine trade will illustrate the importance of the empire-wide Roman trade in agricultural commodities, as well as innovation it fostered as consumers and producers sampled the best produce from around the ancient world. Already by 5th century Greece, a tradition had developed ranking wines and other agricultural products by region,[99] and the Roman sources reveal a comprehensive technical vocabulary to describe the qualities of fine wine,[100] an elaborate hierarchy of *grands crus*,[101] and a vivid

---

[86] See Miller 1969; Thüry and Walter 1997; Amigues 2005; Thurmond 2006: 263-71. For the wide range of spices and condiments used by the Greeks, many already attested by Classical Greek sources, see Garcia Soler 2001: 341-67.

[87] See Thurmond 2006: 263 citing Miller 1969: 28-9; 112-8. See also Thüry and Walter 1997: 33 note 59 for further bibliography.

[88] Miller 1969: 8-9.

[89] Miller 1969: 23-5; 82-3; Thurmond 2006: 263-4. For the impact of the discovery of how to exploit the monsoons and the massive size of many of the merchant ships in this trade, see Casson 1991.

[90] Ciaraldi 2007: 114. The House of the Vestals had bay, oregano, pepper, sesame, mint, thyme or savory, coriander, and fennel. See Ciaraldi 2007: 145-6.

[91] Van der Veen 1998a: black pepper, capers, chicory, coriander, cumin, fennel, rue, mint, mustard, fenugreek, lotus, and basil.

[92] Pliny, *NH* 12.28 and 58, after Ciaraldi 2007.

[93] Pliny, *NH* 12.29.

[94] Miller 1969: 82-3.

[95] Thüry and Walter 1997: 36-9 Table 4.

[96] Cappers 2006; Ciaraldi 2007: 114-5.

[97] Bakels and Jacomet 2003: 550.

[98] Van der Veen 1998a; Van der Veen 1998b.

[99] Dalby 2000b: 137-9.

[100] Thurmond 2006: 155, citing Billiard 1913.

literary and agro-touristic landscape of the country's fine wine-producing regions.[102] By the time of Pliny, Cato the Elder's advice on the varieties of grape available to a winemaker served only to show "how great an advance civilization has made in the past 230 years."[103] The pace of innovation is clear even from our abbreviated accounts of the grape varieties available to contemporary vintners.[104] The constant quest to discover more productive, and better tasting varieties spawned a significant trade in vines,[105] as well as new creations like the Gallic Allobrogica and Biturica,[106] which were almost immediately transplanted into Italian vineyards. Although he and Columella only discuss 34 different vine cultivars, Pliny claims that there were at least 80 ancient grape varieties known to produce outstanding wine, two thirds of them from Italy.[107] Hugh Johnson, writing in the 1970's, argued that only around 50 modern grape varieties were of interest to wine growers.[108] Roman winemakers were so willing to experiment because of the profits to be made in such a broad market, should one produce a superior product.[109] Wines from prestigious regions, like Falernian,[110] could command four times the price of ordinary table wines,[111] although Greco-Roman wine culture was more oriented to making good quality wine in large quantities for a broad market, rather than catering to the social snobbery of an elite, as in *ancien régime* France, where a Margaux or La Fite could sell for sixteen times the price of the product of a lowly peasants' vineyards.[112]

Several decades of amphora studies provide ample evidence that wine was traded on a massive scale throughout the Mediterranean and beyond. Given that amphoras were presumably reused as containers, often for years,[113] taken off site for use in drainage

---

[101] For a sketch of these grands crus, already legendary by the time of Augustus, and their development over the course of the empire, see Tchernia 1986: 184-93; 272-8.

[102] See, for example, Parker 1990; Leary 1999; Dalby 2000a: 21-81.

[103] Pliny, *NH* 14.45. Note how Columella uses thoroughbred race-horse breeding as a metaphor for the way winemakers ought to select the best cultivars (Col. 3.9.4-6).

[104] Pliny, *NH* 14.13-99; Col. 3.7.1-9.9; Tchernia 1986: 350-7; Dalby 2003: 163-7. For further references from a wider range of sources, see André 1953. For a discussion of the principal varieties, see de Angelis 1995: 183-91. For Italian wine varieties worthy of note in some of the principal sources, see Billiard 1913: 70-8; André 1961: 165-76; Tchernia 1986: 322-41; de Angelis 1995: 200-2; Dalby 2003: 354-7.

[105] Note Columella's boasts about the value of his quicksets, which were derived from common Italian grape varieties and sold on the local market. See Col. 3.3.11. Elsewhere, he claims that the best vines from throughout the world have been introduced into cultivation in Italy. See Col. 3.8.5.

[106] Col. Pliny, *NH* 14.26-8.

[107] Pliny, *NH* 14.87. See further Brun 2003: 28. In Medieval France, by way of contrast, knowledge of varietals had been almost entirely lost, only to be revived in the 15th century. See Jackson 2008: 28.

[108] Johnson 1971: 22-5.

[109] Tchernia 1986: 116-9; Purcell 1985; Carandini 1989; Purcell 1995. A number of sources suggest fine wines like Falernian were as much as four times as expensive as ordinary wines (Bouvier 2000: 128) and even higher prices were paid for exceptional or rare vintage wines (Tchernia 1986: 36).

[110] See Dalby 2000a: 48-50.

[111] See Tchernia 1986: 36-7; Bouvier 2000: 128.

[112] Lachiver 1988: 361-2. See Tchernia 1986: 37 for the range of price differentials in 18th and 19th century France, varying according to region from 9 or 10:1 up to 26:1 in another. As Dion 1952 points out, wines were often judged on the social rank of the seigneur of the chateau, which produced them, as much as on the actual taste of the wine.

[113] Carlson 2003: 590; Slane 2005; Monsieur 2007. Specific amphora types were often manufactured in many workshops scattered over huge distances, and arguably then sold and filled, often in a different location, and with a variety of contents, making the use of amphora evidence for trade in specific

works,[114] or recycled as building material,[115] and that wine would also have been transported in *dolia* or barrels, or overland in massive wineskins, leaving no archaeological trace,[116] their quantitative analysis is always likely to under-estimate the full scale of ancient trade, but does provide ample confirmation of its scope.[117] In fact, despite its biases, the diachronic recovery rate of shipwrecks tends to suggest that by the early Roman Empire trade in the Mediterranean likely exceeded that in the Medieval and early Modern period.[118] Greek wine producers from the Aegean developed and began exporting wines into the Western Mediterranean from the late 6th and 5th century,[119] inviting vigorous competition from the wines of Magna Grecia and Campania and the creation of a more integrated Mediterranean market from the 4th through the 2nd centuries BC.[120] Over the course of the late Republic and Principate, despite the continued popularity and prestige of Greek wines,[121] the centre of gravity of the wine trade shifted to the West, into Spain and North Africa,[122] and, most importantly, Italy.[123] Roman Italy created a wide range of *grands crus* and inexpensive wines exported in great quantity into Gaul,[124] and as far as Britain,[125] Egypt[126] and India.[127] The greatest legacy of Roman agriculture today, however, was the adaptation of the vine to regions in France and Germany long considered too cold for successful cultivation, laying the foundation for one of the world's great wine cultures.[128] Creating new vines suitable for Northern

---

commodities very complex. See Laubenheimer 1985; Panella 2001: 191-2; Rauh 2005; Pons Pujol 2007: 453-4.

[114] Pensavento Mattioli 1998.

[115] Peacock and Williams 2005: 146 describe an entire harbour at Myos Hormos built almost entirely out of crushed Dressel 2-4 amphoras. See also Étienne and Mayet 2004: 140-1 and figs. 142-3.

[116] Dion 1959: 137; Tchernia 1986: 138-40; Desbat 1997; E. Marlière in Brun and Laubenheimer 2001: 181-203; Brun 2005: 66-8; De Sena 2005. This consideration is critical in Tchernia's refutation of some of the rash claims of a crisis in Italian viticulture in the 2nd and 3rd centuries B.C.

[117] See surveys in Peacock and Williams 1986; Empereur and Hesnard 1987; Whitbread 1995; Panella 2001; Bonifay 2004; Martin-Kilcher 2005. On the problems of quantification, see Empereur 1982; Tchernia 1986: 75-7; Carreras Montfort 2006. For bibliographical guides to amphora studies, see the references in Panella 2001: 212. For the scale of Baetican amphora production facilities, see, e.g. Tremoleda i Trilla 2007.

[118] Parker 1992; Jurišić 2000; Wilson 2001; Rauh 2003: 103-13; De Callataÿ 2005; Jongman 2007a; Wilson 2009b. See also Scheidel 2009 and the response by Wilson, however.

[119] Whitbread 1995; Cook and Dupont 1998: 142-91; Lawall 2007: 267-9. The importance of the wine trade to cities such as Thasos and Mende is clear from, e.g., Salviat 1986; Papadopoulos and Paspalas 1999; Garlan 1999. For the archaic trade in the West, see Van der Mersch 1996. For the Hellenistic period, see, e.g., Empereur and Hesnard 1987; Lund 1993; Rauh 1999; Finkielsztejn 2001.

[120] Will 1982; Tchernia 1986: 66-74; Empereur and Hesnard 1987; Van der Mersch 1994; Will 1997; Van der Mersch 2001; Lawall 2007.

[121] Tchernia 1986: 100-7; Brock and Wirties 2000; Martin-Kilcher 2005: 268-9.

[122] Brun 2004b: 185-259; 261-302.

[123] See Peacock and Williams 1986: 25-7; Tchernia 1986, *passim*; Panella 2001: 187-8; 192-6; Brun 2004a: 159-86; 2004b: 7-60.

[124] Tchernia 1986: 74-94.

[125] Tchernia 1986: 83-4.

[126] Rathbone 1983; Brun 2004b: 143-83.

[127] Tchernia 1986: 152-3; 404 carte 9; Will 1991; Rauh 2003: 95-103; Tomber 2005a; 2005b; 2008: 81; 149-50; 154; 156-7; Abraham 2007.

[128] See Dion 1959: 77-166; Lachiver 1988: 19-55; Brun and Laubenheimer 2001; Brun 2005: *passim*.

France was challenging enough,[129] but the Romans were ambitious and confident enough to create vineyards in Germany, [130] and even in Britain![131] Ausonius and Fortunatus lauded the fine wines of the Moselle,[132] and recent excavations have uncovered twenty villas, each furnished with two large wine presses, along a 20 km stretch of the river.[133] As Brun argues plausibly,[134] cauldrons excavated at several wine-making villas were used to boil down *sapa* to trigger adequate fermentation of grapes, which had not ripened fully in this cold climate.

Large scale wine production, most of it produced by peasants on small plots,[135] is also well attested for *ancien régime* France, and wine represented one of the few high-value cash crops in what was otherwise an under-developed agrarian regime,[136] but the poverty of the 18th and 19th century working classes offered little scope for a mass trade. Even in the 19th century, when France was the world's dominant wine producer, with 40% of the world's vineyards, a remarkably small proportion of her wine production was exported, only around 2.6% in 1828, for example.[137] It would be hard to conceive that the great Greco-Roman wine producers, island states like Thasos, Chios, Cnidus or Rhodes, or even Baetica, Campania, or Southern Gaul, exported such a small proportion of their production.

The production and trade of wine and olive oil is highly visible archaeologically, and therefore well known, but the economic importance of the trade in livestock, cheese, meat and fish products, fruits, nuts and vegetables, to say nothing of cereals, will have been just as impressive. I have dealt elsewhere with the scale of the market for meat, which included not just domestic animals, but fowl, game, fresh fish, and shellfish, often farmed,[138] to which one must add a massive trade, second only to that in wine and olive oil, in garum and salted or cured fish or meat.[139] It is worth re-iterating, though, how

[129] Dion 1959: 148-51. As Dion 1959: 91 suggests, the experience of Hellenistic vintners in the Cimmerian Bosporus or Kertsch penninsula, where the vines were supposedly buried in soil to protect them from frost in the winter, will have been helpful in extending the geographical reach of the grapevine. See also Pecirka 1970a; 1970b; Saprykin 1995; Brun 2004a: 118-21.
[130] Kreuz 2001; Gilles 2001; Brun 2005: 131-52.
[131] Brun 2005: 129-30.
[132] Brun 2005: 148.
[133] Kühnen 2003. For the wines of the Moselle, see Brun 2005: 134-51.
[134] Brun 2005: 142-6.
[135] Lachiver 1988: 244-7.
[136] See Dion 1959; Lachiver 1988 for extensive discussion. Lavergne 1855 frequently alludes to some of the limitations of the French agrarian economy in the mid-19th century, in his comparison with contemporary English farming.
[137] See Lachiver 1988: 393-4; 582.
[138] Kron 2002; Kron 2004a; Kron 2008a; Kron 2008b: 79-86.
[139] For increasing evidence for the ubiquity of garum and salsamenta of Spanish mackerel, even outside the Mediterranean, in the Roman era, see Ervynk et al. 2003: 437, and note Étienne and Mayet 2002: 181-210; 2004: 1: 197-204. The recent analysis of deposits at Xanten show almost 19% of amphoras held fish products, compared to 29% for wine and 41% for olive oil (Berni Millet 2007: 20 fig. 1). For the trade in fish sauce, see Curtis 1984; Étienne and Mayet 1998a; 1998b. For remains of fish found intact in transport amphoras, see, e.g. Bruschi and Wilkens 1996, and for salted or cured meat, even game-birds like thrushes, see Lauwerier 1993; Bruni 2000: 38; 329-41; Carlson 2003: 589-90 and note 32; Thurmond 2006: 210-9; Leguilloux 2006; Fercoq du Leslay and Lepetz 2008.

effectively livestock can be transported great distances by sea, and by land, on the hoof.[140]

Regarding the other major products, we will content ourselves with one example. Fruit consumption, like that of meat, fish and fresh vegetables, tends to be highly elastic, and is therefore dependent upon prosperous urban populations for much of their market, but fruit orchards, unlike market gardens, need not be located in the immediate suburbs of substantial towns or cities.[141] Fruit trees are generally less labour intensive than vegetables, require less manure, are more tolerant of poor soil and arid conditions, and require only periodic watering rather than continuous irrigation.[142]

Even leaving aside the olive, fruit and nuts were the object of a highly developed trade over great distances in the Greco-Roman world. Fruit trees, vines, and olives were planted in such numbers that Varro could describe Italy as one vast orchard,[143] figs were sometimes cheap enough to be fed to fish, or to geese or even pigs raised for their 'fig-forced' livers,[144] and the fruit of Italy, Greece, Spain, Syria and North Africa was shipped by river and sea through much of the Roman world.[145] Cato the Elder helped seal the fate of Rome's old enemy, when he held out a fig he had bought in a Roman market, picked just a couple of days before in Carthage.[146] A number of shipwrecks have preserved amphoras packed with fruit,[147] particularly dates, which the Greeks and Romans never succeeded in cultivating domestically.[148] Moreover, the Roman provinces reveal many fruit imported from the Mediterranean,[149] and finds at the Red sea ports show that coconuts were brought from India.[150] Both Pliny and Columella give detailed instructions for the packing and storage of fruit,[151] which are scientifically sound,[152] and both practical and economically viable for transport to market, as is clear from the use of similar methods in 19th century California.[153] It is instructive to contrast the elaborate precautions taken by Roman growers, careful to present unblemished fruit to demanding

[140] Bruni 2000: 330; 337; Kron 2008b: 107 and note 217. Yeo 1946 and Yeo 1948 still provide the fullest overview of the literary evidence, but his theories about environmental degradation should be dismissed, as he discounts the role of intensive mixed farming or the quality of Roman range management. See Kron 2004a; Kron 2004b, now with Ciaraldi 2007: 75-85; Kron 2005c.

[141] It was advantageous to fruit growers to cultivate near a town, but hardly essential. Even before the rise of railroads, few fruit orchards were located in Surrey, close to the London market (Marshall 1817: 402) but were largely spread through Kent, Sussex, and the Westcountry, and also carried by sea from Devon, Cornwall, and Wales. See Webber 1972: 50-3.

[142] Many California fruit growers eventually rejected regular irrigation in favour of trenching and working the soil well and keeping down weeds (Wickson 1891: 79-80), although for certain trees and in certain conditions it is helpful, if not essential. See Wickson 1891: 207-29 for the methods used.

[143] Varro, *R.R.* 1.2.6.

[144] Cappers 2006: 165.

[145] Pliny, *NH* 15.105: "in one kind of food the aid of India is invoked, in another that of Egypt, Crete, Cyrene, and every land in turn."

[146] Pliny, *NH* 15.75.

[147] Peacock and Williams 1986: 96; 106; 109; Sadori et al. 2009: 47. For imported dates at Pompeii, see Ciaraldi 2007: 146.

[148] Amigues 2007: 99-100.

[149] See, for example, Bakels and Jacomet 2003: 547; Buxó 2005: 205-9 with further references.

[150] Cappers 2006: 162-3; 166-7; Abraham 2007: 289-90.

[151] Pliny, *NH* 15.59-67; Col. 12.10.1-16.5. Further references in de Angelis 1995: *passim*.

[152] See Thurmond 2006: 174-86; Cappers 2006: 147-51.

[153] See, e.g. Wickson 1891: 237-8; 285.

customers, with the casual packing of up to 72 lbs of fruit in simple wicker baskets in late 19th century England, until imports of North American apples carefully packed in wooden boxes inspired some merchants to try new methods.[154] A sealed amphora with the pits of 162 peaches, recovered at Aquileia,[155] not only attests to the careful packing, transport and sale of what is a very delicate and perishable fruit,[156] but the fact that all of the peaches, once analyzed, came from the same cultivar, suggests an orchard carefully selected and propagated from slips for uniform, presumably high-quality fruit.[157]

Although tolerable yields of mediocre fruit can be harvested with minimal inputs of labour, the competitiveness of the market demanded a much more professional and labour-intensive approach. Theophrastus' works, and the advice of the Roman agronomists, demonstrate a thorough mastery of principles of budding, grafting, and training fruit trees in order to breed new varietals, clone the best trees in nurseries, and maximize their yield.[158] One Roman *pomarius* was so eager to show off his virtuosity, that he grafted a tree at Tivoli so that it "had nuts on one branch, berries on another, while in other places hung grapes, pears, figs, pomegranates and various sorts of apples."[159] In addition to introducing new fruit trees from Africa and the Near East, including pomegranates, peaches, nectarines, quinces, sweet cherries, jujube, carob, damson, and citrus fruit,[160] new species were created, like the apple-pumpkin, said to be a cross between the melon and the quince,[161] or the apple-plum and almond-plum,[162] and innumerable new cultivars were bred or selected, with Pliny listing 41 pear varieties, 28 fig cultivars, 22 types of apple, 8 of the cherry, 7 of the quince, and 5 varieties of peach and plum.[163] The lists preserved for us are naturally rather selective, for, as Pliny points out: "The rest of the fruits produced by trees can scarcely be enumerated by their appearance or shape, let alone by their flavours and juices, which have been so frequently modified by crossing and grafting."[164] Although he claims that the art of grafting and cross-breeding has long since been perfected by Greco-Roman growers, so that little

---

[154] See Webber 1972: 111-2.
[155] See Sadori et al. 2009: 47.
[156] Pliny, *NH* 15.40; Amigues 2007:
[157] Of course, many Romans also grew fruit trees in their home gardens. See Jashemski 1974; 1979a; 1979b: *passim*; Jashemski 1987.
[158] Pliny, *NH* 15.35-117; Col. 5.10.1-11.15. The literary sources for Roman arboriculture are discussed in depth by de Angelis 1995, but could repay even further study, using archaeobotanical evidence and incorporating comparative analysis. See also White 1970: 228-9; 247-61; Flach 1990: 258-274; De Angelis 1997; Farrar 1998: 67-71; Amigues 2007: 95-8. More scholarly attention has been paid to the ancients' methods of grafting and pruning vines. See Billiard 1913: *passim*; Brun 2003: 29-44. Compare Wickson 1891 for the rapid growth of fruit orchards in the rather similar climatic conditions of California.
[159] Farrar 1998: 168. See further the even more elaborate celebration of Roman virtuousity in grafting in Virgil, G. 2.78-82, ably defended against modern assumptions that such methods were seen as 'unnatural' by Lowe 2010. For Roman grafting, see Pease 1933 and further references in Lowe 2010. For a broader history of grafting, see Mudge et al. 2009.
[160] Thurmond 2006: 173; Pliny, *NH* 15.39; 42. It has also been suggested recently that there is some possible evidence for the introduction of the pineapple (pers. comm. A. Touwaide).
[161] See Pliny, *NH* 19.65; Ciaraldi 2007: 138.
[162] Pliny, *NH* 15.42.
[163] Pliny, *NH* 15.37-56; 68-74. See further de Angelis 1995: 53-119 for discussion of some of the major species and varieties. The discussion of the many varieties of figs from Greek, Oriental and Italian regions is particularly striking. See de Angelis 1995: 60-2.
[164] Pliny, *NH* 15.35.

technical progress is possible, he notes a number of successful new cultivars developed within the last thirty or even the last five years.[165] Significantly, the creators of many of these fruit varieties, drawn from very diverse social backgrounds, from freedmen to senators, became famous for their innovation, with their names given to the Scaudian and Sceptian apples, the Dolabellian pear, and the Appian quince, to name just a few.[166] The diversity of fruit grown in Italy or imported by sea, is very impressive. In addition to the fruit already listed, literary sources or archaebotanical studies attest to the consumption of mulberries, blackberries, blueberries, myrtleberries, cornelberries, serviceberries, rowanberries, strawberries, figs, grapes, sorbs, apricots, citrons, bitter oranges, lemons, medlars, cucumbers, gourds, melons, including watermelons, and such nuts as acorns, hazelnuts, chestnuts, beechnuts, almonds, pistachios, walnuts, and pine nuts.[167]

The importance of fresh fruit in the Roman diet, and the skill of Roman *pomarii* is clear from literary evidence as well as innumerable still lives and garden paintings.[168] As one historian of modern market gardening remarks: "In the National Museum at Naples is a mural from the ruins of Pompeii showing a bowl of grapes, pears and apples equal, it would seem, in size and quality, to anything that can be produced today."[169] Archaeobotany confirms that growers did indeed produce larger fruit,[170] with many different species and cultivars,[171] including several which would disappear from Central Europe for centuries with the decline of the empire.[172] These studies also confirm that fruit was not a luxury in the Roman diet, but was consumed in a wide range of households,[173] legionary camps,[174] and even desert quarries like Mons Claudianus. At the latter site we find dates, grapes, figs, pomegranates, watermelons, melons, cucumbers, citrons, sycamore-figs, black mulberries, olives, Arabian jujubes, Assyrian plums, Doum palm fruit, persea fruit, as well as pine nuts, walnuts, almonds, and hazelnuts.[175]

Roman trade networks stimulated agricultural production for export throughout the empire, even in under-populated semi-deserts, which would be abandoned to small-scale nomadic pastoralism for centuries after the fall of the Empire. The scale of North African olive oil production is now notorious from the remains of a dense network of

---

[165] Pliny, *NH* 15.40. The selection and breeding of fruit did not develop on any scale in England until the last half of the 19th century. See Webber 1972: 58-9.

[166] Cato, *Agr*. 7.2; 143.3; Col. 5.10.11; Pliny, *NH* 15.49-50; 15.102-3; Farrar 1998: 168. Compare William's Bon Chretien pear, introduced in the 1770's to North America by Enoch Bartlett and still well known under that name. See Webber 1972: 56-7.

[167] André 1961: 42-3; Brothwell and Brothwell 1969: 30-47; Jacomet et al. 2002; Bakels and Jacomet 2003; Van der Veen and Wasylikowa 2004: 214; Thurmond 2006: 174-5; Ciaraldi 2007: 137-9; 144-5. For those attested to by Classical Greek sources, see Garcia Soler 2001: 101-25.

[168] De Caro and Boriello 2002; Jashemski, Meyer and Ricciardi 2002; Ciaraldi 2007: 143-4.

[169] Webber 1972: 19.

[170] Sadori et al. 2009: 49-53.

[171] For references to studies in Italy see the bibliographies in Ciaraldi 2007; Sadori et al 2009. For Central Europe, see Bakels and Jacomet 2003. A useful database of archaeobotanical studies is online at http://www.archaeobotany.de.

[172] Jacomet et al. 2002; Bakels and Jacomet 2003; Livanda and Van der Veen 2008.

[173] House of the Vestals at Pompeii, these were combined with apples, pears, quinces, sorbs, peaches, plums, the Naples medlar, melons, citrus fruit, most likely citrons or lemons, almonds, walnuts and hazelnuts. See Ciaraldi 2007: 137-9.

[174] Davies 1971: 132; Bakels and Jacomet 2003.

[175] Van der Veen 1998a; Van der Veen 1998b; Van der Veen 2001.

massive press complexes,[176] but olive oil was only part of a rich mixed farming regime producing cereals, wine, livestock, wild and domestic fowl.[177] Less well known, perhaps, Mauretania built up a significant wine industry, with a surprising reputation for quality[178] and huge complexes such as that at Kherbet Agoub, the largest discovered so far, with 21 wine presses and the capacity to produce up to 5,000 hl at one time.[179] In the East, Egypt built its olive oil industry, launched by the Ptolemies in the Fayoum, into a major producer,[180] and even succeeded in creating a *grand cru* centred on Lake Mareotis, suitable for the first time for significant exports,[181] and managed intensively using up-to-date equipment and methods, as confirmed by papyri.[182] Even more indicative, perhaps, of the way trade, in this case the caravan trade linking Roman markets with the Near East,[183] quickened the pace of economic development, we have evidence of wine and olive oil production taking hold in the new Roman province of Arabia in the Jordanian desert.[184] This remarkable fusion of traditional methods of run-off farming, exploited on an unprecedented scale,[185] with Hellenistic and Roman expertise in wine, olive oil and tree fruit production, anticipates by two millennia the success of modern Israeli farmers in making the Negev desert bloom, an achievement directly inspired by the study of Nabataean methods.[186]

THE STATE, INFRASTRUCTURE, AND SUBSIDIARY INDUSTRIES: DRAINAGE, IRRIGATION AND TOOLS

Although the high demand fostered by social equality, urbanization, and trade played the most important role in permitting Greco-Roman farmers to exploit the land to its full potential, the structure of their society also provided a powerful stimulus to agriculture in more indirect and subtle ways. Centuriation, which still marks the modern countryside of Italy, France, Tunisia, and Spain, is the most visible indication of the transformative effect of Roman culture upon the landscape,[187] but it had also had a long history among the Greeks, as we see at a number of sites, particularly Metapontum or

[176] Mattingly 1988a; 1988b; 1993a; 1993b; 1996; 2009; Hitchner and Mattingly 1993; Hitchner 2002; Brun 2004b: 185-259.
[177] See Marcone 1997: 183-93; Kehoe 1988; Bonifay 2004: 478-9. For a similar mixed farming regime and diversified economy in Baetica, another massive olive oil exporter (Étienne and Mayet 2004), see Ponsich 1998; Revilla 2007. For the exploitation of pre-desert for arable farming using runoff farming, see Barker et al. 1996, and below.
[178] Brun 2004b: 232-44.
[179] Brun 2004b: 233-8.
[180] Evenari, Shanan and Tadmor 1982: 95-147.
[181] Brun 2004b: 150-1.
[182] Rathbone 1991: 244-60; Brun 2004b: 143-50.
[183] Young 2001.
[184] Brun 2004b: 138-41.
[185] Oleson forthcoming, chapter 8.
[186] Evenari, Shanan and Tadmor 1982: 179-219.
[187] See Dilke 1971; Campbell 1996; Campbell 2000; Chouquer and Favory 2001. The bibliography is immense. See Chouquer et al. 1996-7 for references on centuriation (3000 titles) and Toneatto 1994-5 for works on the gromatici (1500 titles).

Heraclea Pontica in the Chersonnese.[188] Many historians have significantly underestimated the agricultural significance of centuriation. For small farmers, who could struggle to drain their land and bring their produce to market otherwise,[189] the state's organization and mobilization of the collective labour of the rural population in the broader public interest would have been invaluable. Extensive drainage works typically preceded centuriation, or the creation of a new road network, and were then extended throughout the countryside in the form of drainage ditches flanking the rectilinear road network dividing up the land into *centuriae*.[190] Such works helped facilitate the full agricultural exploitation of the countryside, particularly in low-lying or clay soils, or in rich river valleys, such as the Pomptine marshes,[191] or the Po valley, which was transformed into one of Italy's richest agricultural regions, in large part through Aemilius Scaurus' important land reclamation initiative.[192] Although lauded in Continental Europe for its model of large estates and capital intensive agriculture, systematic attention to drainage seems to have been far less common in England, as Dickson noted,[193] where, even in the high farming period of the mid-19th century, it was frequently restricted to the estates of select improving landlords, despite the serious effect poor drainage could have upon yields.[194] The Roman agronomists explain the techniques of drainage in detail,[195] and archaeological fieldwork provides ample confirmation of what we would suspect from the practice of centuriation, that drainage was a constant concern of most ordinary Roman farmers, not just the agronomists. Ground-breaking interdisciplinary studies in Southern France have documented the careful maintenance of elaborate systems of drainage ditches,[196] and tens of thousands of amphoras, buried to provide effective subsoil drainage, have been happened upon in excavations. Most assemblages have been found in urban contexts, but some were likely intended to drain arable fields.[197]

The Roman commitment to public infrastructure, mastery of hydraulic engineering, and effectiveness in mobilizing labour also boosted agricultural productivity through irrigation, often on an extremely large scale.[198] Centuriation allowed a broad cross-section of the farming population to benefit, since drainage ditches can also be used to channel water for irrigation, but dedicated canals and aqueducts had to be built for any

[188] Uggeri 1969; Adamesteanu and Vatin 1976; Carter 1990; 2004; 2006; Yntema 1993: 81-3; Campbell 2000: xlv; Guldager Bilde and Stoba 2006; Karjaka 2008; Collin-Bouffier 2008. See also the articles by Clavel-Leveque, Plana-Mallart, Kolesnikov and Jacenko, and of Kuznecov in Brunet 1999b.

[189] Wordie 1974: 600 note 1 quotes the English agricultural writer Arthur Young attacking the advocates of small farms, saying: "Who will drain his land at an expense of two to three pounds an acre?"

[190] See, for example, Quilici-Gigli 1992.

[191] See especially Quilici-Gigli 1992; Attema and de Haas 2005.

[192] Dall'Aglio 1995. For the success of the Romans in draining the Po valley more fully than at any time before the end of the 19th century, see Kron 2005a: 478-82.

[193] As noted by White 1970: 190.

[194] See, e.g., Caird 1968 [1852]: 256-7; 470-2. For the use of the ridge and furrow system to ameliorate the effect of yields of poorly drained land, note Kerridge 1992: 9-10.

[195] See White 1970: 146-50.

[196] See Berger 2008 for a good recent overview. For a similar phenomenon in the Roman *suburbium*, see Buccellato et al. 2009: 540-7; Egidi 2009: 502-13.

[197] Pensavento Mattioli 1998.

[198] White 1970: 151-72; Butzer et al. 1985; Hodge 1992: 246-53; Horden and Purcell 2000: 237-57; 585-8; Thomas and Wilson 1994; Leveau 1997; Wilson 1999; Coates-Stephens 2003; Valenti 2003: 94-6; Beltrán Lloris 2006; Gualtieri 2008; Bannon 2008: 249-61; Wilson 2009a.

large-scale projects. In the Po valley, an impressive infrastructure of navigable canals was created,[199] which were essential for drainage and could also be exploited for irrigation, but our best evidence for large scale irrigation now comes from the canal system of Roman Spain,[200] better understood with the recent discovery of a detailed inscription regulating access to irrigation in several small rural communities. Decisions were taken on a democratic basis, by majority vote, it should be noted, with water rights and labour and maintenance obligations apportioned according to the amount of land, which owners or cultivators must irrigate.[201] This inscription also helps to confirm that the legendary irrigated agriculture of the Medieval Spanish *huerta*[202] is a revival of Roman practice, largely attributable to the respect of the Arab conquerors for ancient Greco-Roman scientific and agronomic traditions.[203]

The most intensive irrigation was reserved for market gardening, but irrigated meadows were both productive and lucrative, and they are described in detail by the agronomists.[204] Some arable and tree crops benefit from intermittent irrigation as well, usually in times of drought or specific seasons, but most of our evidence for such irrigation, at least on any scale, comes from semi-arid regions such as Spain, North Africa, and certain parts of Greece, particular the Cycladic islands. Run-off irrigation in desert and semi-desert conditions is well attested among the Nabataeans, and in North Africa, as we have noted above. Although research in this field has lagged for Classical or Hellenistic Greece, and some have questioned whether irrigation could have been practiced on any scale,[205] recent work on Delos has revealed an extensive infrastructure designed to capture and store the rainwater resources of this arid island,[206] permitting the market gardening, viticulture, oleiculture, and mixed farming revealed by epigraphy and archaeozoological studies.[207] Studies of the emergence of irrigated agriculture in Greece over the past few decades amply attest to the viability and potential impact of irrigation,[208] and should warn us against under-estimating its role in the more intensive ancient regime,[209] particularly given the evidence for the importance of Greek market gardening,[210] and the advances in water-lifting technology achieved by Hellenistic scientists and engineers.[211]

---

[199] Kron 2005b: 475 note 194.
[200] See Beltrán Lloris 2006: 167-70; Prieto 2008.
[201] Beltrán Lloris 2006. This Spanish inscription and the long-famous Lamasba inscription (CIL VIII.18587) are the only such regulations of any substance to survive (Beltrán Lloris 2006: 166 note 63) but legal and literary sources show that fair and efficient regulation of water-rights was standard Roman practice (Bannon 2008).
[202] See Butzer et al. 1985; Horden and Purcell 2000: 222-3; 586-7.
[203] As first argued by Butzer et al. 1985, based on archaeological and topographic evidence of continuities in settlement and systems of irrigation canals. Lagardère 1997 provides striking evidence of the continuity between Arab and late Roman viticulture in Spain.
[204] Col. 2.16-7; Plin. 18.258-63; Varro, *R.R.* 1.31.5; Pallad. 10.10; Quilici Gigli 1989; Bannon 2008: 258-9.
[205] Krasnilkoff 2002.
[206] Brunet et al. 2003; Brunet 2008. Also note the literary evidence in Bruun 2000.
[207] Brunet 1999a; Brun 2000; Leguilloux 2000a.
[208] Islam, Manos and Kamruzramman 2005.
[209] Osborne 1992b; Hanson 1999: 60-3; Horden and Purcell 2000: 244-7; Garcia Soler 2001: 43-72; Amigues 2005; Amigues 2007; Margaritis and Jones 2008:162.
[210] As Crouch 1984: 362 notes.
[211] Oleson 1984.

Transport infrastructure played a critical role in facilitating the large-scale trade in the relatively bulky agricultural commodities like grain, wine, and olive oil so important to the intensification and specialization of agricultural production. Since most large Greco-Roman cities were on the sea or a navigable river, harbours were the most important link in the supply chain.[212] The great harbours of Carthage, the Peiraeus, Syracuse, Rhodes, Aegina, Thasos, Cnidos, and Alexandria were joined by even more massive harbour facilities at Puteoli, Ostia, and Portus,[213] all significantly larger than the crude small harbours, which served the Mediterranean in the 19th century.[214] Hydraulic concrete was used to great effect to build moles and breakwaters for artificial harbours throughout the Mediterranean, most ambitiously, perhaps, in creating the harbour of Caesarea Maritima along a stretch of ocean marked by powerful and potentially destructive currents.[215] Rome, with its quays and *horrea* stretching for kilometers along the Tiber,[216] was as great as many of these maritime harbours, but other river ports, such as Londinium, or even Pisa, were highly developed,[217] and the creation of navigable canals made for a relatively comprehensive and inexpensive system of transport.[218] Transport was least expensive by water, but land transport in the Roman era was as highly developed as in any pre-industrial society,[219] facilitated by the superb Roman road network, which was still a cause of wonder through the 19th century,[220] and by the roads built into the centuriation grid, which, while unpaved, were presumably leveled and kept passable in winter by drainage ditches. They would have been more than adequate to transport agricultural products and manure easily by oxcart to the paved road network.

In addition to this elaborate infrastructure of harbours, canals, roads, and drainage ditches, we should not neglect the more direct investments in rural aqueducts,[221] cisterns, dams, and agricultural terraces,[222] which helped to prevent erosion, along with the field fences, hedges and plantings of trees, which served as boundary markers, windbreaks, and sources of fodder, brush and lumber.[223]

Even more important, though, was the massive Greek, Carthaginian, and Roman investment in farm buildings, store-rooms, granaries, stables, and sheepfolds,[224] as well

---

[212] See Blackman 1982; Rickman 1988; Gallina Zevi and Turchetti 2004; Keay and Millett 2006; Blackman 2008; Hohlfelder 2008.
[213] See Keay and Millett 2006.
[214] See Houston 1988: 560-4.
[215] See Oleson 1988; Oleson et al 2004; Oleson et al. 2006; Oleson et al. 2008; Blackman 2008 for references.
[216] Rickman 1971; Rickman 1980: 129-43; France 2008: 484 note 1.
[217] See, e.g., Pasquinucci and Weski 2004. For the great importance of rivers in ancient trade networks, note also, e.g., Pliny, *NH* 3.54-5 on the Tiber, and Auson. *Ordo nob. urb*. 6; 10; 19.12-22 on Trèves, Arles, and Narbonne.
[218] See, for example, the network of canals in Northern Italy (Uggeri 1987: 337-47; Kron 2005a: 447-8 and note 205) as well as Egypt, Gaul and Germany (Grewe 2008: 333-6).
[219] Adams 2007; Raepsaet 2008.
[220] See Chevallier 1997; Quilici 2008 for good overviews. See Dalby 2000b: 14-20 for evocations of the relative ease of travel in literature.
[221] De Franceschini 2005: 305-12; Gualtieri 2008; Wilson 2009a.
[222] Quilici-Gigli 1989; Brunet 1990; Hitchner 1995; Foxhall 1996; Horden and Purcell 2000: 234-7; Price and Nixon 2005; Harfouche 2007; Quilici-Gigli 2008.
[223] Kron 2005c: 297-8.
[224] Day 1932; Carrington 1932; Rossiter 1978; Flach 1990: 233-45; Leguilloux 2003; Massendari 2007; Kron 2008a: 183.

as processing facilities such as wine and olive presses, and wine cellars,[225] and expensive facilities for *pastio villatica*, including massive maritime fishponds of hydraulic concrete, aviaries, game farms, and columbaria.[226] As James Caird argued strenuously, 19th century English landlords and tenant farmers generally failed to invest properly in farm buildings or stables,[227] but this certainly was not the case in the ancient Mediterranean. The number, size, and standard of construction of Roman villas and farms, which has emerged from more than two centuries of excavation and intensive surveys is truly staggering for a pre-industrial society.[228] Archaeologists have generally ignored ordinary farmhouses, concentrating on luxury villas, which, as Roman social values demanded,[229] were also working farms,[230] but enough *villae rusticae*[231] have been studied to show that farmers of all social levels concurred with the high farming philosophy of Caird and the Roman agronomists. The villas and farms excavated to date suggests a tentative typology for Roman Italy of the late Republic and Principate, consisting of three broad classes: small farms, very rarely excavated, with a handful of examples as small as 55 m^2 attested, but generally ranging from 150 to 250 m^2, a middle rank of substantial *villae rusticae* of between 400 and 600 m^2, and larger villas of 1,000 m^2, often well over 2,000 m^2 in size.[232] The work of Day and Carrington, and the signs of comfort and elegant decoration in most of the farmhouses, which fall within the two smaller classes,[233] suggests that these belonged largely to owner-occupiers, occasionally helped by a few slaves.[234] The evidence of Greek farmhouses, many of which can be clearly identified, by the careful study of field divisions, as small family farms intensively working a few hectares of land, further confirms the prosperity of these *autourgoi*, and the pride they took, and the money they invested, in their farm buildings.[235]

As we have seen, farmers benefitted from the rapid growth of the ancient building trades, with access to cheap mass-produced roof tiles and many skilled contractors with experience in quickly building solid structures in mud-brick and concrete. Likewise, we

---

[225] Rossiter 1981; Brun 2004a; 2004b; 2005, *passim*.

[226] Rinkewitz 1984; Bortuzzo 1990; Giacopini, Marchesini and Rustico 1994; Higginbotham 1997; Kajava 1998-9; Olive and Deschler-Erb 1999; Lafon 2001; Kron 2008a; 2008b; 2008c: 85-6; Marzano and Brizzi 2009.

[227] Caird 1852: 77; 89; 135; 152; 222; 430.

[228] For recent surveys in Spain and Italy, for example, see Ponsich 1974-91; Gorges 1979; 1991; Fernandez Castro 1982; De Franceschini 1998; 2005; Pergola et al. 2003; Carandini et al. 2006: 559-610; Marzano 2007; Carandini 2009; Cifani 2009. For the density of farms and villas near Rome, see, e.g., Bedini 1997; Goodchild 2007: 80-120; Buccellato et al. 2009: 533 and notes 6-8. A recent survey of Tusculum has revealed a landscape densely packed with lavish villas, revealed by scatters of pottery and roof tiles extending over as much as 20-50,000 m^2, some just hundreds of meters apart. See Valenti 2003: 56-63.

[229] See, e.g., Cato, *Agr.* 3.2; Varro, *R.R.* 3.2.6; Col. 1.4.8; Niquet 2000.

[230] Most notably, the great villa of Settefinestre, which extended over 3,600 m^2, over 2,000 m^2 of which was devoted to the accommodation of the slave workforce and other agricultural uses. See Carandini 1985 and the remarks in Rathbone 2008: 312.

[231] Day 1932; Carrington 1932; Rossiter 1978; De Caro 1994; Rathbone 2008.

[232] Rathbone 2008: 311-2.

[233] Carrington 1931; Day 1932; Flach 1990: 233-45; De Caro 1994; Ortalli 2006.

[234] As Rathbone 2008: 317-8 points out, the small (decorated) *villa rustica* of Villa Regina at Boscoreale published by de Caro 1994 has graffiti suggesting the presence of three individuals, with names suggesting that they were most likely slaves, at the peak of its prosperity, when it had been expanded to 450 m^2.

[235] See, e.g., Pecirka 1970; Jones et al. 1973; Jones 1975; Lohmann 1993; Saprykin 1995; Brun 2004a: 118-21; Carter 2006.

see a significant improvement in the quality of tools and the application of machinery and labour saving devices in agriculture, as has been argued in depth by a number of scholars,[236] as part of a broad and wide-ranging critique of the long-lived caricature of Classical technological stagnation.[237] Although the economic importance of such innovations should not be exaggerated,[238] the Roman sources allude to a large range of ploughs, including the heavy *carrus*, with wheels, coulter and mouldboard, designed to work dense clay soils, and archaeological work shows the widespread introduction of a wide range of sturdy metal ploughshares and coulters.[239] Agricultural implements seem to have been made overwhelmingly, if not exclusively, of iron, and, like Roman carpenters' tools,[240] were professionally made and well-designed, with most virtually identical to modern implements for gardening, hand cultivation, or vine-dressing.[241] As we can see from the wide range of such tools found in Pompeii, even relatively modest smallholders seem to have bought them from manufacturers, as recommended by Cato,[242] rather than hand-crafting their own tools out of wood, as Tuscan *contadini* of the 19th and early 20th centuries often did.[243] Although these fine metal tools will have been somewhat more efficient, their use is arguably more important as an indication of the prosperity of Roman farms, and their integration into the urban economy, as buyers as well as sellers.

Most attention has been given to the development of the *vallus*, a type of animal-powered harvesting machine very similar to an implement successfully used in modern Australia.[244] One probably should not exaggerate the importance of these technologies, however, as Kolendo properly noted, noting that the introduction of the *vallus* and even the *irpex* drawn by oxen or equids were of most value for extensive farming or to compensate for labour shortages.[245] The wine or oil press was arguably a more important machine promoting the intensification of Greco-Roman agricultural production.[246] The deserts of North Africa have provided the most fertile environment for recovering ancient presses, but it is now increasingly clear that such machines were ubiquitous throughout the Mediterranean, Egypt, the Near East, and the Roman provinces of temperate Europe.[247] We have already noted the complex at Kherbet Agoub with 21 presses. Another with 17 presses has been uncovered at Senam Semana in Tripolitania,[248] and

[236] White 1967; Kolendo 1985; Forni 1989; Forni 2002; Forni 2006.
[237] See, e.g. Wilson 2002; Oleson 2008.
[238] Brunt 2003.
[239] Gow 1914; Frayn 1979: 130-4; Kolendo 1980: 71-84; Forni 1989; Forni 2002; Marbach 2004a; 2004b; 2006-7; Forni 2006.
[240] Gaitzsch 1980.
[241] Kolendo 1985, Amouretti 2000; Forni 2002; 2006; Marcone 2006. For the vinitor's knife see Brun and Laubenheimer 2001: 151-3 and an identical tool from Medieval France illustrated in Lachiver 1988: plate IV.
[242] Pointedly noted by Gummerus 1906.
[243] De Simonis 1982: 506-519. For the literary sources describing wicker used for baskets and occasionally for some crude agricultural tools, see Frayn 1979: 134-8.
[244] Kolendo 1960; 1980: 155-178; White 1970: 182-3.
[245] Kolendo 1980: 149-54; 175-7.
[246] See Drachmann 1932; Mattingly 1993a; Foxhall 1993; Frankel 1999: 68-75; Curtis 2001: 307-11; Brun 2003: 58-62; 148-56; 208-17; 2004b: 300-2; Ayalon, Frankel and Kloner 2009.
[247] Brun 2003; 2004a; 2004b; 2005: *passim*.
[248] Brun 2004b: 190.

there is also a marked increase in their size and power. One press at the massive Lusitanian villa of Torre de Palma has a beam 12 m long and a 4500 kg counterweight capable, theoretically at least, of exerting a pressure of 29 tons.[249]

FOOD PROCESSING

The study of Greco-Roman food processing technology has received detailed attention in two excellent recent monographs,[250] so we can be relatively brief here. Thurmond has performed an extremely important service, showing that the advice of the Roman agronomists, particularly Columella, regarding food processing and preservation is generally consistent with the principles in the modern scientific literature.

Food processing and preservation played an increasingly important role as foodstuffs were traded over large distances. Although livestock, and even fish or shellfish,[251] could be transported live, and some fresh and unprocessed produce could be traded long distances with appropriate packaging, as we have seen, perishable foods could be transported more safely, and preserved for consumption out of season, if dried, smoked, cured or salted, or packed in wine, sugar syrups based on honey or boiled must, vinegar, or brine.[252] Many of these techniques had been developed in the Near East, but in the Greco-Roman period we see innovation, not only in the diversity of products and the repertoire of techniques, but an increase in the scale of production and in the capital invested in new technologies and equipment.[253] Massive water mills, capable of supplying thousands of people, as at the Barbegal complex,[254] were used to mill flour and even to knead dough, allowing bread to be baked for popular distribution on an unprecedented scale and presumably at a much reduced cost.[255]

Wine production is arguably the most complex and demanding branch of ancient food processing, an art as well as a science, and one which confirms the expertise of the Roman agronomists, as Billiard has documented in great detail.[256] Moreover, Thurmond[257] addresses most of Billiard's criticisms of Greco-Roman practice, noting, to take just one example, that the addition of salt, which so outraged Billiard, is a well-attested practice among French winemakers today.[258] In fact, the agronomists were aware of many of the methods used by modern wine-makers to protect or stabilize wine and ensure its quality, to restart a feeble fermentation process, or to restore wine, which was in danger of spoiling.[259] The acidity of wine, critical to its long-term health and stability, flavour, and effective fermentation, was regulated by adding either gypsum (calcium sulfate) in order to fine wine, precipitating its impurities, improve the colour,

[249] Brun 2004b: 301.
[250] Curtis 2001; Thurmond 2006. See also Curtis 2008.
[251] Kron 2008a: 211; 213.
[252] See Thurmond 2006: 165-87; 212-9; Curtis 2008: 384.
[253] As noted by Wilson 2008b: 409-11.
[254] Leveau 1996.
[255] Wikander 2008: 141-52; Thurmond 2006: 37-72; Wilson 2008b: 406-8; Curtis 2008: 373-9.
[256] Billiard 1913: 424-536.
[257] Thurmond 2006: 111-64.
[258] Thurmond 2006: 151. The same point is also noted by Tchernia 1986: 105.
[259] Thurmond 2006: 128-55; cf. Ribéreau-Gayon et al. 2006; Jackson 2008.

and reduce acidity,[260] or marble dust or chalk (calcium carbonate) in order to increase acidity.[261] Bentonite was used to clarify wine, and has been proven by modern research to be very effective in removing proteins, which can create offensive flavours,[262] and sulfur dioxide was used to fumigate the tanks, *dolia*, and amphorae, which would come into contact with wine, destroying potentially harmful yeast cultures and microbes.[263] The recent work of Bouvier shows that there is a great deal more to be learned through careful interdisciplinary study, and through experimental archaeology by wine-makers who are willing to put the recommendations of the ancients to the test.[264]

The preservation of fish by salting or smoking, and the production of *garum* or fish sauce is the another Greco-Roman food processing industry, which was organized on a massive scale,[265] comparable to the trade in wine and olive oil in its geographical reach, as we have already noted.[266] Since fish can be salted and dried on a very large scale on crude reed platforms on the seashore, or brined in *dolia*,[267] leaving little archaeological trace, we cannot read too much into the limited evidence discovered so far for the Classical and Hellenistic salt-fish industry in the Eastern Mediterranean and the Black sea, which is very well attested by literary sources.[268] In the Western Mediterranean, however, in the Punic, late Republican and early Imperial periods concrete fish salting tanks were used, offering direct evidence that this industry was creating salt-fish products on a scale surely unprecedented at any time before or since. At Lixus in Mauretania Tingitania, a series of 10 factories, capable of producing ca. 1,013,000 m^3 of *salsamenta* and *garum* have been excavated.[269] Smaller facilities varying from 3-20 m^3 capacity have been found at a wide range of sites, including the coasts of Italy, Mediterranean Gaul and Libya, but the largest fish-salting vats have been found all along the coast of Southern Spain, Brittany, North Africa, and the Black Sea, with capacities ranging from 30 to over 100,000 m^3, with factories at Troia I/II reaching capacities of 600,000 m^3.[270]

Other processed animal products such as cheese,[271] ham,[272] and sausage[273] were likely produced and exported on a comparable, if not even greater, scale. We know of a massive export of hams and cheese from Northern Italy, in the region of Parma known to

[260] Thurmond 2006: 152-3.
[261] Thurmond 2006: 153, taking issue with Billiard 1913: 502-3.
[262] Thurmond 2006: 146.
[263] See Romano and Suzzi 1993, with discussion of the importance of sulfur dioxide in modern vine production.
[264] Bouvier 2000; 2001.
[265] See Wilson 2006; 2009.
[266] For recent work on these industries, see Sanquer and Galliou 1970; Peacock 1974; Curtis 1984; 1986; 1991; 2001: 317-21; 403-17; 2008: 385-6; 403-16; Ponsich 1988; Étienne and Mayet 1998c; 2002; Étienne, Makroun and Mayet 1994; Bekker-Nielsen 2005; Wilson 2006; 2007; Pons Pujol 2006: 71-7; 2009: 97-124; Kehoe 2007: 556; Lagóstena, Bernal and Aréval 2007.
[267] Desse and Desse-Berset 2000.
[268] Curtis 2001: 317-8. See now Bekker-Nielsen 2005.
[269] Curtis 2001: 411 note 27.
[270] Wilson 2006, with reference to excavation reports. For a recently found factory in Brittany, see Driard 2008, with further references and a map (p. 238 fig. 1) of recently discovered fish sauce factories in the region.
[271] Auberger 2000; Dalby 2000b: *passim*; Dalby 2003: 80-1; Thurmond 2006: 193-207.
[272] Thurmond 2006: 212-7. For offerings of hams to the gods at a French sanctuary, see Fercoq du Leslay and Lepetz 2008.
[273] Frost 1999; Dalby 2000b: 39; 67-8; 218-9; Dalby 2003: 294-5; Thurmond 2006: 220-2.

this day for the same products, as Thurmond points out,[274] and literary sources as well as papyri make it clear that sausages and cheeses in particular were prime articles of trade, available in a wide range of regional specialties, with cheese from Turkey and the Cyclades and Lucanian sausages imported into Egypt.[275]

A huge range of agricultural commodities, from cheap staples to the most expensive and exotic, were readily available, fresh, preserved, and in many processed forms, to fill the robust demand for fine food in the markets, restaurants, and inns of Classical and Hellenistic Greece, and throughout the Roman Empire, in particular. Although almost all are mere names to us, successful professional chefs had begun publishing cook-books to advertise their skill by the 5th or 4th century B.C., and the sophisticated and prosperous consumers to whom they catered, ensured that Greco-Roman food production had a powerful impact well beyond the farm, providing value added for the economy, employment for maritime traders, packagers, retailers, food processors, cooks, and restauranteurs, and ample nourishment and enjoyment for the public.

[274] Thurmond 2006: 217.
[275] Papathomas 2006: 196.

REFERENCES

Abraham, S.A. 2007. "South Asian Perspective," in *Berenike 1999/2000*, eds. Sidebotham, S.E., and Wendrich, W. Los Angeles: 285-94.

Adamesteanu, D., and Vatin, Cl. (1976) "L'arrière pays de Métaponte," *CRAI*: 110-23.

Adams, C. E. P. (2007) *Land Transport in Roman Egypt. A Study in the Economics and Administration in a Roman province*. Oxford.

Allen, R. C. (2008) "The Nitrogen Hypothesis and the English Agricultural Revolution: A Biological Analysis," *Journal of Economic History* 68:182–210.

Allen, R.C., Bengtsson, R., Dribe, M., eds. (2005) *Living Standards in the Past: New Perspectives on Well-being in Asia and Europe*. Oxford.

Ambrosoli, M. (1983) "L'opus agriculturae di Palladio: volgarizzanti e identificazione dell'ambiente fra tre e quinquecento," *Quaderni Storici* 52: 227-54.

Ambrosoli, M. (1997) *The Wild and the Sown: Botany and Agriculture in Western Europe, 1350-1850*. Cambridge.

Amigues, S. (2005) "Végétaux et aromates de l'Orient dans le monde antique," *Topoi* 12/ 13: 359-383.

Amigues, S. (2007) "L'exploitation du monde végétal en Grèce classique et hellénistique," *Topoi* 15: 75-125.

Amouretti, M.-C. (1981) "Des agronomes latins aux agronomes provençaux," *Provence Historique* 124: 83-100.

Amouretti, M.-C. (1986) *Le pain et l'huile dans la Grèce antique. De l'araire au moulin.* Paris.

Amouretti, M.-C. (2000) "L'artisanat indespensible au fonctionnement de l'agriculture," in *L'Artisanat en Grèce ancienne. Les Productions, les diffusions*, eds. F. Blondé and A. Muller. Paris: 147-64.

Amouretti, M.-C., and Brun, J.-P. (1993) *La production du vin et de l'huile en Méditerrannée de l'âge du Bronze à la fin du XVIème siècle.* Athens.

André, J. (1953) "Contribution au vocabulaire de la viticulture: Les noms de cépages," *Revue des Études Latines* 30: 126-57.

André, J. (1961) *L'alimentation et la cuisine à Rome.* Paris.

Applebaum, S. (1975) "Some Observations on the Economy of the Roman Villa at Bignor, Sussex," *Britannia* 6: 118-132.

Attema, P., De Haas, T. (2005), "Villas and farmsteads in the Pontine region between 300 BC and 300 AD: a landscape archaeological approach," in Santillo Frizell and Klynne, eds. (2005): 97-112.

Ayalon, E., Frankel, R., Kloner, A. eds. (2009) *Oil and Wine Presses in Israel from the Hellenistic, Roman and Byzantine Periods*. Oxford.

Auberger, J. (2000) "Du prince au berger tout homme a son content du fromage... Odyssée 4,87-88," *Revue des Études Anciennes* 113: 1-41.

Bakels, C., Jacomet, S. (2003) "Access to Luxury foods in Central Europe during the Roman Period: The Archaeobotanical Evidence," *World Archaeology* 34: 522-47.

Banaji, J. (2001) *Agrarian Change in Late Antiquity. Gold, Labour, and Aristocratic Dominance.* Oxford.

Bannon, C.J. (2008) *Gardens and Neighbours: Private Water Rights in Roman Italy.* Ann Arbor.

Barker, G., Gilbertson, D., Jones, B., and Mattingly, D., eds. (1996) *Farming the Desert: The UNESCO Libyan Valleys Archaeological Survey. Vol. 1: Synthesis*. Paris.
Bedini, A. (1997) "Modi di insediamento e bonifica agraria nel suburbio di Roma," in Coen and Quilici-Gigli, eds. (1997): 165-84.
Begley, V., and de Puma, R.D., eds. (1991) *Rome and India: The Ancient Sea Trade*. Madison.
Bekker-Nielsen, T., ed. (2005) *Ancient Fishing and Fish Processing in the Black Sea Region.* Aarhus.
Beltrán Lloris, F (2006) "An Irrigation Decree from Roman Spain: *The Lex Rivis Hiberiensis*," *Journal of Roman Studies* 96: 147-96.
Berger, J.-F. (2008) "Étude géoarchéologique des réseaux hydrauliques romains en Gaule Narbonnaise (haute et moyenne vallée du Rhône): apports à la gestion des ressources en eau et à l'histoire agraire antique," in E. Hermon, ed. (2008): 107-21. Rome.
Berni Millet, P. (2007) "Einige Aspekte des Handels mit römischen Amphoren in Xanten," *Xantener Berichte* 14: 19-24.
Billiard, R. (1913) *La Vigne dans l'Antiquité.* Lyon.
Bintliff, J. L. (1997) "Further considerations on the population of ancient Boeotia," in *Recent Developments in the History and Archaeology of Central Greece*, ed. Bintliff, J.L., 231-252. Oxford.
Bintliff, J. L. (2006) "City-Country Relationships in the 'Normal Polis'," in *City, Countryside, and the Spatial Organization of Value in Classical Antiquity*, eds. R.M. Rosen and I. Sluiter. Leiden & Boston: 13-32.
Bintliff, J. L. (2007) "Considerations for Creating an Ottoman Archaeology in Greece," in *Between Venice and Istanbul: Colonial Landscapes in Early Modern Greece*, eds. S. Davies and J.L. Davis. Athens: 222-236.
Bintliff, J. L. (2008) "Considerations on Agricultural Scale-Economies in the Greco-Roman World," in *Feeding the Ancient Greek City*, eds. R. Alston and O. van Nijf. Leuven: 7-32.
Bintliff, J., and Snodgrass, A. 1988. "Off-Site Pottery Distributions: A Regional and Interregional Perspective," *Current Anthropology* 29: 506-513.
Blackmann D. J. (1982) "Ancient harbours in the Mediterranean," *International Journal of Nautical Archaeology* 9: 79-104.
Blackmann D. J. (2008) "Sea transport, 2. Harbors," in Oleson, ed. (2008): 638-70.
Blazquez, J.M. (1992) "The Latest Work on the Export of Baetican Olive Oil to Rome and the Army," *Greece and Rome* 39: 172-88.
Bonifay, M. (2004) *Etudes sur la ceramique romaine tardive d'Afrique*. Oxford.
Bonner, C.J. (2008) *Gardens and Neighbours: Private Water Rights in Roman Italy*. Ann Arbor.
Bortuzzo, N. (1990) “Il leporarium. Un esempio di pastio villatica nella Gallia Cisalpina di tarda età repubblicana-prima età imperiale? Alcune ipotesi sulla Transpadana orientale,”*Aquileia Nostra* 66: 85-112.
Boscherini, S. (1970) *Lingua e scienza greca nel De agri cultura di Catone*. Rome.
Bouvier, M. (2000) "Recherches sur les goûts des vins antiques," *Pallas* 53: 115-33.
Bouvier, M. (2001) *Les saveurs du vin antique*. Paris.
Bowman, A.K., Rogan, E., eds. (1999) *Agriculture in Egypt from Pharaonic to Modern Times.* Oxford.

Bowman, A.K. (2009) "Quantifying Egyptian Agriculture," in Wilson and Bowman, eds. (2009): 177-204.
Brien-Poitevin, F. (1996) “Consommation des coquillages marins en Provençe dans l’époque romaine,” *Revue Archéologique de la Narbonnaise* 29: 313-20.
Brothwell, D., and Brothwell, P. (1969) *Food in Antiquity: A Survey of the Diet of Early Peoples*. Baltimore.
Brun, J.-P. and Laubenheimer, F. (2001) "La viticulture en Gaule," *Gallia* 58: 1-260.
Brun, J.-P. (1997) "L'introduction des moulins dans les huileries antiques," in Meeks and Garcia (1997): 69-78.
Brun, J.-P. (2000) “The production of perfumes in antiquity: the cases of Delos and Paestum,” *American Journal of Archaeology* 104: 277-308.
Brun, J.-P. (2003) *Le vin et l'huile dans la Méditerranée antique. Viticulture, oléiculture et procédés de transformation*. Paris.
Brun, J.-P. (2004a) *Archéologie du vin et de l’huile de la préhistoire à l’époque hellénistique.* Paris.
Brun, J.-P. (2004b) *Archéologie du vin et de l’huile dans l’Empire romain.* Paris.
Brun, J.-P. (2005) *Archéologie du vin et de l'huile en Gaule romaine*. Paris.
Brunet, M. (1990) "Terrasses de cultures antiques: l'exemple de Délos, Cyclades," in M. Provansal, ed. *L'agriculture en terrasses sur les versants méditerrannéens: histoire, consequences sur l'evolution du milieu*: 5-11. Aix-en-Provence.
Brunet, M. (1999a) "Le paysage agraire de Délos dans l'antiquité," *Journal des savants* (1999): 1-50.
Brunet, M. (1999b) (ed.) *Territoires des cités grecques*. Athens.
Brunet, M. (2008) "La gestion de l'eau en milieu urbain et rural à Delos dans l'antiquité," in Hermon ed. (2008): 25-40
Brunet, M. et al. (2003), "L'eau à Délos," *Bulletin du Correspondence Héllenique* 127: 516-25.
Bruni, S., ed. (2000) *Le navi antiche di Pisa: Ad un anno dall'inizio delle ricerche.* Florence.
Brunt, L. (2003) "Mechanical innovation in the industrial revolution: the case of plough design," *Economic History Review* 56: 444-77.
Bruschi, T., Wilkens, B. (1996) "Conserves de poisson à partir de quatre amphores romaines," *Archaeofauna* 5: 165-169.
Bruun, C. (2000) "Water legislation in the ancient world," in O. Wikander, ed. *Handbook of Ancient Water Technology*: 537-604. Leiden.
Buccellato, A., D'Annibale, M.L., and Torri, C. (2009) "Elementi reconstruttivi del paesaggio suburbano d'epoca Repubblicana nel territorio compreso tra la via Laurentina moderna e il corso del Tevere," in Jolivet et al., eds. (2009): 531-555.
Buck Sutton, S., ed. (2000) *Contingent Countryside: Settlement, Economy, and Land Use in the Southern Argolid since 1700*. Stanford.
Burford, A. (1993) *Land and Labour in the Greek World.* Baltimore.
Burnett, J. (1979) *Plenty and Want.* London.
Butzer, K.W. Mateu, J.F., Butzer, E.K., and Kraus, P. (1985) "Irrigation Agrosystems in Eastern Spain: Roman or Islamic Origins?" *Annals of the Association of American Geographers*, 75: 479-509.
Buxó, R., Chabal, L., and Gardeisen, A. (2003) " Étude carpologique de la place 123:

problématique de la présence de restes de semences et de fruits dans un espace urbain non construit," *Lattara* 16: 193-217.
Buxó, R. (2005) "Étude carpologique des puits de Lattes," *Lattara* 18: 199-219.
Caird, J. (1852) *English Agriculture in 1850-51* (2nd edn., 1968, London)
Campbell, B. (1996) "Shaping the rural environment: Surveyors in Ancient Rome," *Journal of Roman Studies* 86: 74-99.
Campbell, B. (2000) *The writings of the Roman land surveyors.* London.
Campbell, B.M.S. (2000) *English Seigniorial Agriculture 1250-1450*. Cambridge.
Capogrossi Colognesi, L. (1982) *L'Agricoltura Romana. Guida storica e critica.* Bari.
Cappers, R.J.T. (2006) *Roman foodprints at Berenike. Archaeobotanical evidence of subsistence and trade in the eastern desert of Egypt*. Los Angeles.
Carandini, A. (1985) *Settefinestre. Una villa schiavistica nell'Etruria romana.* 3 vols. Modena.
Carandini, A. (1988) *Schiavi in Italia. Gli strumenti pensanti dei romani fra tarda Repubblica e medio Impero.* Rome.
Carandini, A. (1989) "Italian wine and African oil. Commerce in a world empire," in *The Birth of Europe: Archaeology and social development in the first millenium B.C.* Rome: 16-24.
Carandini, A. (2009) "I paesaggi del suburbio," in Jolivet et al. eds. (2009): 295-310.
Carlsen, J., Ørsted, P. and Skydsgaard, J.-E. eds. (1994) *Landuse in the Roman Empire.* Rome.
Carlson, D.N. (2003) "The Classical Greek Shipwreck at Tektaş Burnu, Turkey," *American Journal of Archaeology* 107: 581-600.
Carrié, J.-M. (2004) "Vitalité de l'industrie textile à la fin de l'antiquité: considérations économiques et technologiques," *Antiquité Tardive* 12: 13-43.
Carreras Montfort, C. (2006) "A quantitative approach to the amphorae from Xanten: a more comprehensive view of the long-distance Roman trade," in *Kolloquium Römischen Amphoren der Rheinprovinzen unter besonderer Berücksichtigung des Xantener Materials: Kolloquium, Regionalmuseum Xanten, 13.-15. Januar 2004*. Xanten: 25-39.
Carrington, R.C. (1931) "Studies in the Campanian 'Villae rusticae'," *Journal of Roman Studies* 21: 110-130.
Carter, J.C., Thompson, S.M., and J. Trelogan (2004) "Dividing the Chora," in *Polis und Chora.* eds. F. Korb, E. Müller-Luckner. Munich: 127-45.
Carter, J.C. (1990) "Metapontum - Land, Wealth and Population," in *Greek Colonists and Native Populations*, ed. J.P. Descoeudres. Oxford: 405-441.
Carter, J.C. (2006) *Discovering the Greek Countryside at Metaponto.* Ann Arbor.
Casson, L. (1991) "Ancient Naval Technology and the Route to India," in Begley and de Puma, eds. (1991): 8-11.
Chandezon, C. (2003) *L'élevage en Grèce, fin Ve – fin Ier siècle a.C. L'apport des sources épigraphiques*. Bordeaux.
Chevallier, R. (1997) *Les voies romaines*. Paris.
Chouquer, G. et al. (1996-7) *Les formes du paysage*, II-III. Paris.
Chouquer, G. and Favory, F. (2001) *L'arpentage romain: histoire des textes - droit - techniques.* Paris.
Ciaraldi, M. (2007) *People and Plants from Ancient Pompeii. A new approach to urbanism from the microscope room.* London.

Cifani, G. (2009) "Indicazioni sulla proprietà agraria nella Roma arcaica in base all'evidenza archeologica," in Jolivet et al., eds. (2009): 311-24.
Clarke, M.H. (2000) " Dowry and inheritance: their relationship to land fragmentation and risk reduction on Methana," in Buck Sutton, ed. (2000): 169-99.
Coates-Stephens, R. (2003) "Gli acquedotti in epoca tardoantica nel suburbio," in Pergola, Santangeli Valenzani, and Volpe, eds. (2003): 415-36.
Coen, A., Quilici-Gigli, S., eds. *Uomo, aqua e paesaggio, Atti dell'incontro sul tema: irregimentazione delle acque e trasformazione del paesaggio antico, Santa Maria Capua Vetere, 1996*. Rome.
Collin-Bouffier, S. (1999) "La pisciculture dans le monde grec. État de la question," *Melanges de l'École Française de Rome* 111: 37-50.
Collin-Bouffier, S. (2008) "L'organisation des territoires grecs antiques et le gestion de l'eau," in Hermon ed. (2008): 41-54.
Cook, R.M., and Dupont, P. (1998) *East Greek Pottery*. London.
Cool, H.E.M. 2006. *Eating and Drinking in Roman Britain*. Cambridge.
Crouch, D.P. (1984) "The Hellenistic Water System of Morgantina, Sicily," *American Journal of Archaeology* 88: 353-65.
Curtis, R.I. (1984) "The salted fish industry of Pompeii," *Archaeology* 37: 58-59, 74-75.
Curtis, R.I. (1986) "A. Umbricius Scaurus of Pompeii," in *Studia Pompeiana et classica in honor of Wilhelmina F. Jashemski, 1: Pompeiana,* ed. W.F. Jashemski. New Rochelle: 19-49.
Curtis, R.I. (1991) *Garum and Salsamenta. Production and Commerce in Materia Medica.* Leiden.
Curtis, R.I. (2001) *Ancient food technology.* Leiden.
Curtis, R.I. (2008) "Food processing and preparation," in Oleson ed. (2008): 369-92.
Dall'Aglio, P. L. (1995) "Considerazioni sull'intervento di Marco Emilio Scauro nella pianura Padana," in Quilici and Quilici Gigli, eds. (1995): 87-93.
Dalby, A. (1996) *Siren feasts: a history of food and gastronomy in Greece.* London - New York.
Dalby, A. (2000a) *Empire of Pleasures: Luxury and Indulgence in the Roman World*. London-New York
Dalby, A. (2000b) "To feed a king. Tyrants and the search for quality in agriculture and food," in *Paysage et Alimentation dans le Monde Grec*, ed. J.-M Luce. Toulouse: 133-44.
Dalby, A. (2003) *Food in the Ancient World from A to Z*. London-New York.
Daubeny, C. (1857) *Lectures on Roman husbandry*. Oxford.
Davies, J.K. (2007) "Classical Greece: Production," in Scheidel, Morris and Saller, eds. (2007): 333-61.
Davies, R. W. (1971) "The Roman Military Diet," *Britannia* 2: 122-42.
Davis, J.L. and Davies, S. eds. (2007) *Between Venice and Istanbul: Colonial Landscapes in Early Modern Greece*. Princeton.
Day, J. (1932) "Agriculture in the life of Pompeii," *Yale Classical Studies* 3: 166-208
De Angelis, A. (1997) "La coltivazione delle piante da frutto: un' occasione di rilettura dei testi agronomici latini," *Quaderni Urbinati di Cultura Classica* 55: 71-88.
De Angelis, A. (1995) *La coltivazione delle piante da frutto nella letteratura agronomica latina: dalla produzione alla conservazione dei frutti*. Rome.
De Callataÿ, F. (2005) "The Graeco-Roman economy in the super long run: Lead, copper,

and shipwrecks, *JRA* 18: 361-72.
De Caro, S. (1994) *La villa rustica in località Villa Regina a Boscoreale.* Rome.
De Caro, S. and Boriello, M., eds. (2002) *La natura morta nelle pitture e nei mosaici delle città vesuviane*. Naples.
De Franceschini, M. (1998). *Le ville romane della X Regio (Venetia et Histria).* Rome.
De Franceschini, M. (2005). *Ville dell'Agro Romano*. Rome.
De Simonis, P. et al. (1983) *Cultura Contadina in Toscana*. 2 vols. Florence.
Desbat, A. (1997) "Le tonneau antique: questions techniques et problème d'origine," in Meeks and Garcia, eds. (1997): 113-20.
Desse, J., Desse-Berset, N. 2000. "Salaisons de poissons marins aux marges orientales du monde gréco-romain. Contributions de l'archéozoologie," *Mélanges de l'École Française de Rome, Antitquité* 112: 119-134.
De Vries, J. (1974) *The Dutch Rural Economy in the Golden Age, 1500-1700.* New Haven.
De Vries, J. (1984) *European Urbanization. 1500-1800*. Cambridge, MA.
Dickson, A. (1788) *The Husbandry of the ancients in two volumes*. Edinburgh.
Diedrich, S. (2007) *Römische Agrarhandbücher zwischen Fachwissenshaft, Literatur und Ideologie.* Berlin.
Dilke, D.A.O. (1971) *The Roman Land Surveyors: Introduction to the Agrimensores*. Newton Abbot.
Dimbleby, G.W., and Jones, M.K. eds. (1981) *The environment of man: The Iron Age to the Ango-Saxon period*. Oxford.
Dion, R. (1952) "Querelle des anciens et des modernes sur les facteurs de la qualité du vin," *Annales de Géographie* 61 (328): 417 - 431.
Dion, R. (1959) *Histoire de la vigne et du vin en France des origines au XIXe siècle.* Paris.
Dommelen, P. van, and Gómez Bellard, C. eds. (2008) *Rural landscapes of the Punic World*. London.
Doukas, K.A. (1945) "Agrarian Reform in Greece," *American Journal of Economics and Sociology* 5: 79-92.
Drachmann, A.G. (1932) *Ancient oil mills and presses*. Copenhagen.
Driard, C. (2008) "Un établissement romain specialisé dans les productions de salaisons et sauces de poisson à Étel (Morbihan, France)," in *Archéologie du Poisson. 30 ans d'archéo-ichthyologie au CNRS*, eds. P. Béarz, S. Grouard, and B. Clavel. Antibes: 237-44.
Dumont, J.C. (2000) "Columelle 3,3,8-14: Calcul économique ou argument de vente?" *Pallas* 53: 63-72.
Egidi, R. (2009) "Insediamenti, strade e sistemi di bonifica agraria nel suburbio orientale (X municipio), tra il V ed il II secolo A.C.," in Jolivet et al., eds. (2009): 497-517.
Eiring, J. and Lund, J., eds. (2005) *Transport amphorae and trade in the eastern Mediterranean*. Aarhus.
Empereur, J.-Y. (1982) "Les anses d'amphores timbrées et les amphores : aspects quantitatifs," *Bulletin de correspondance hellénique* 106: 219-233.
Empereur, J.-Y. and Hesnard, A. (1987) "Les amphores hellénistiques du monde égéen," in *Céramiques hellénistiques et romaines*, II, eds. P. Léveque, J.-P. Morel. Franche-Comté: 8-23.
Erdkamp, P. (2005) *The Grain Market in the Roman Empire: A Social, Political, and*

Economic Study. Cambridge.
Ervynk, A., Van Neer, W., Hüster-Plogmann, H., and Schibler, J. (2003) "Beyond affluence: the zooarchaeology of luxury," *World Archaeology* 34: 428-41.
Étienne, R., and Mayet, F. (1998a) "Le *Garum* à Pompéi: production et commerce," *Revue des Études Anciennes* 100: 199-215.
Étienne, R., and Mayet, F. (1998b) "Les mercatores de saumure hispanique," *Mélanges de l'École française de Rome, Antiquité* 110: 147-65.
Étienne, R., and Mayet, F. (1998c) "Cartographie critique des établissements de salaisons de poisson dans la péninsule Ibérique," in É. Rieth, ed., *Méditerranée antique. Pêche, navigation, commerce*: 33-60. Paris.
Étienne, R., and Mayet, F. (2002) *Salaisons et sauces de poisson Hispaniques.* Paris.
Étienne, R., and Mayet, F. (2004). *L'huile hispanique*. 2 vols. Paris.
Étienne, R., Makroun, Y., Mayet, F. (1994) *Un grand complexe industriel à Troia (Portugal).* Paris.
Evenari, M., Shanan, L., and Tadmor, N. (1982) *The Negev: The Challenge of a Desert*, 2nd edn. Cambridge, MA.
Farrar, L. (1998) *Ancient Roman Gardens*. Phoenix Mill, Gloucestershire.
Favory, F., Parodi, A., Poupet, P., and Raynaud, Cl. (1994) "Lunel-Viel et son térritoire. Habitat et occupation des sols en France mediterranée dans l'antiquité et le Moyen Âge: Approches régionales," *Documents d'Archéologie Française* 42: 163-245.
Fercoq du Leslay, G., and Lepetz, S. (2008) "Manger dans les sanctuaires. Salaisons et viande fraîche à Ribemont-sur-Ancre," in *Archéologie du sacrifice animal en Gaule romaine. Rituels et pratiques alimentaires*: 201-206. Montagnac.
Ferdière, A. et al. (2006) *L'histoire de l'agriculture en Gaule: 500 av. J.-C. - 1000 apr. J.-C*. Paris.
Fernandez Castro, M.-C. (1982) *Villas romanas en España*. Madrid.
Finkielsztejn, G. (2001) *Chronologie détaillée et révisée des eponyms amphoriques rhodiens, de 270 à 108 av. J.-C. environ: Premier bilan.* Oxford.
Flach, D. (1990) *Römische Agrargeschichte*. Munich.
Floud, R., Wachter, K., and Gregory, A. (1990) *Height, Health and History – Nutritional Status in the United Kingdom*. Cambridge.
Forbes, H.A. (1992) "The ethnoarchaeological approach to ancient Greek agriculture," in B. Wells, ed. (1992): 87-101.
Forbes, H.A. (2000) "The Agrarian Economy of the Ermionidha around 1700. An Ethnohistorical Reconstruction," in Buck Sutton, ed. (2000): 41-70.
Forbes, H.A. (2007) *Meaning and Identity in a Greek Landscape: An Archeaological Ethnography*. Cambridge.
Forni, G., Marcone, A. eds. (2002) *Storia dell'agricoltura italiana I.2 L'età romana.* Florence.
Forni, G. (1989) "Strumenti aratori in Aquileia Romana: Loro origine, evoluzione, tipologia. Il contesto socio-economico," in *Aquileia Repubblicana e Imperiale.* Udine: 313-34.
Forni, G. (1994) "Le colture agrarie padane e la loro produttività all'epoca della romanizzazione," *Rivista Archeologica dell'Antica Provincia e Diocesi di Como* 176: 17-82.
Forni, G. (2002) "Colture, lavori, tecniche, rendimenti," in G. Forni and A. Marcone, A.,

eds. (2002): 62-156.
Forni, G. (2006) "Innovazione e progresso nel mondo romano. Il caso del agricoltura," in E. Lo Cascio, ed. (2006): 145-79.
Foxhall, L. (1993) "Oil Extraction and processing Equipment in Classical Greece," in M.-C. Amouretti and J.-P. Brun, eds. (1993): 183-200.
Foxhall, L. (1996) "Feeling the earth move: cultivation techniques on steep slopes in classical antiquity," in Shipley and Salmon, eds. (1996): 44-67.
Foxhall, L. (2007) *Olive Cultivation In Ancient Greece. Seeking The Ancient Economy*. Oxford.
Foxhall, L., Jones, M.K., Forbes, H. (2007) "Human ecology and the Classical landscape," in *The Blackwell Companion to Classical Archaeology, eds.* S. Alcock, R. Osborne. Oxford.
France, J. (2008) "Les personnels et la gestion des entrepôts impériaux dans le monde romain," *Revue des Études Anciennes* 110: 483-507.
Frass, M. (2006) *Antike römische Gärten: soziale und wirtschaftliche Funktionen der Horti Romani*. Horn.
Frayn, J.M. (1979) *Subsistence Farming in Roman Italy*. London.
Frost, F. (1999) "Sausage and meat preservation in antiquity," *Greek, Roman and Byzantine Studies* 40: 241-52.
Fussell, G.E. (1971) *Crop Nutrition: Science and Practice before Liebig.* Lawrence, Kansas.
Fussell, G.E. (1972) *The Classical Tradition in West European Farming.* Rutherford, N.J.
Gaitzsch, W. (1980) *Eiserne römische Werkzeuge: Studien zur römischen Werkzeugkunde in Italien den nördlichen Provinzen des Imperium Romanum*, 2 vols. Oxford.
Gallant, T.W. (1991) *Risk and Survival in Ancient Greece: Reconstructing the Rural Domestic Economy*. Cambridge.
Gallina Zevi, A., and Turchetti, R. eds. (2004) *Le strutture dei porti e degli approdi antichi. Atti del II Seminario ANSER, Roma-Ostia Antica, 16-17.4.2004*. Rubettino.
Garcia Soler, M. J. (2001) *El arte de comer en la antigua grecia.* Madrid.
Garlan, Y. (1999) *Les timbres amphoriques de Thasos. 1. Timbres protothasiens et thasiens anciens.* Athens-Paris
Garnsey, P.D.A. (1998) *Cities, Peasants and Food in Classical Antiquity. Essays in Social and Economic History.* Cambridge.
Ghigi, A. (1939) *Poultry farming as described by the writers of ancient Rome: [Cato, Varro, Columella and Palladius]*. Milan.
Giacopini, L.B., Marchesini, B., and Rustico, L. (1994) *L'itticoltura nell'antichità*. Rome
Gilles, K.-J. (2001) "Römischer Weinbau an Mosel und Rhein," in Herz and Waldherr eds. (2001): 57-76.
Goodchild, H. 2007. *Modelling Roman Agricultural Production in the Middle Tiber Valley, Central Italy* (diss. Birmingham)
Gorges, J.G. (1979) *Les villas hispano-romaines*. Paris.
Gorges, J.G. (1992) "Archéologie et economies des campagnes hispano-romaines: vingt ans de bibliographie commentée (1968-1992)," *Mélanges de la Casa de Velázquez* 28-1: 93-142.
Gow, A.S.F. (1914) "The ancient plough," *Journal of Hellenic Studies* 34: 249-75.

Grewe, K. (2008) "Tunnels and Canals," in Oleson, ed. (2008): 319-36.
Grey, C. (2007) "Revisiting the problem of the 'agri deserti' in the Late Roman Empire," *Journal of Roman Archaeology* 20: 362-76.
Gualtieri, M. (2008) "The water supply system of a senatorial estate in Southern Italy (*Oppido Lucano*, PZ)," in Hermon, ed. (2008): 67-75.
Guldager Bilde, P., and Stoba, V.F. (2006) *Surveying the Greek Chora*. Aarhus.
Gummerus, H. (1906) *Der römische Gutsbetrieb als wirtschaftlischer Organismus nach den Werken des Cato, Varro und Columella.* Leipzig.
Habermann, W. (2001) "Die Deklarationen von Kleinvieh (Schafe und Ziegen) im römischen Ägypten. Quantitative Aspekte," in Herz and Waldherr eds. (2001): 77-100.
Hall, A.D. (1908) "Theories of Manure and Fertilizer Action," *Science,* N.S. 28: 617-628.
Halstead, P. "Review of M-C. Amouretti and J.-P. Brun, *La production du vin et de l'huile en Méditerranée*" *Journal of Hellenic Studies* 117 (1997): 242-44.
Hansen, M.H. (2006) *The Shotgun Method: The Demography of the Ancient Greek City-State Culture.* Columbia - London.
Hanson, V.D. (1999) *The Other Greeks: The Family Farm and the Agrarian Roots of Western Civilization*, 2nd edn. New York.
Harfouche, R. (2007) *Histoire des paysages méditerranéens terrassés: aménagements et agriculture*. Oxford.
Hermon, E., ed. (2008) *Vers une gestion intégrée de l'eau dans l'Empire romain.* Rome.
Herz, P. Waldherr, G. eds. (2001) *Landwirtschaft im Imperium Romanum*. St.Katharinen.
Hickey, T.M. (2007) "Aristocratic landholding and the economy of Byzantine Egypt," in *Egypt in the Byzantine World 300-700 AD*, ed. R.S. Bagnall. Cambridge: 288-308.
Higginbotham, J. (1997) *Piscinae - Artificial Fishponds in Roman Italy.* Chapel Hill.
Hitchner, R.B. (1995) "Irrigation, terraces, dams and aqueducts in the region of Cillium (mod. Kasserine). The role of water works in the development of a Roman-African town and its countryside," in *Productions et exportations africaines: actualités archéologiques en Afrique du Nord antique et mediévale*, ed. P. Trousset. Paris: 143-57.
Hitchner, R.B. (2002) "Olive production and the Roman economy: the case for intensive growth in the Roman empire," in *The ancient economy*, eds. Scheidel, S. von Reden. Edinburgh: 71-83.
Hitchner, R.B. (2005) "The Advantages of Wealth and Luxury. The Case for Economic Growth in the Roman Empire," in *The Ancient Economy. Evidence and Models*, eds. J.G. Manning and I. Morris. Stanford: 207-222.
Hitchner, R.B., and Mattingly, D.J. (1993) "Olive production and the Roman economy: the case of intensive growth," in Amouretti and Brun, eds. (1993): 311-18
Hodge, A.T. (1992) *Roman Aqueducts and Water Supply.* London.
Hodkinson, S. (1988) "Animal Husbandry in the Greek Polis." in *Pastoral Economies in Classical Antiquity*, ed. C. R. Whitakker. Cambridge: 35-74.
Hodkinson, S. (1992a) "Imperialist Democracy and Market-Oriented Pastoral Production in Classical Athens," *Anthropozoologica* 16: 53-61.
Hodkinson, S. (1992b) "Politics as a determinant of pastoralism: the case of southern Greece," *Rivista di Studi Liguri* 16: 139-64.
Hodkinson, S. (2000) *Property and Wealth in Classical Sparta*. London-Swansea.

Hohlfelder, R.L. ed. (2008) *The maritime world of ancient Rome. Proceedings of "The maritime world of ancient Rome". Conference held at the American Academy in Rome, 27 - 29 March 2003*. Ann Arbor.
Horden, P., and Purcell, N. (2000) *The Corrupting Sea. A Study of Mediterranean History.* London.
Houston, G.W. (1988), "Ports in Perspective: Some Comparative Materials on Roman Merchant Ships and Ports," *American Journal of Archaeology* 92: 553-564.
Howe, T. (2008) *Pastoral Politics: Animals, Agriculture and Society in Ancient Greece.* Claremont, CA.
Ibn al-'Awwâm (2000) *Le Livre de l'agriculture: Kitab al-Filâha.* Arles.
Isager, S., Skydsgaard, J. (1992) *Ancient Greek Agriculture: An Introduction*. London.
Islam, SMF, Manos, B., and Kamruzzaman, M. (2005) "Long-term productivity growth and sustainability of Greek irrigated agriculture', *Archives of Agronomy and Soil Science* 51: 311-324.
Jackson, R.S. (2008) *Wine Science: Principles and Applications*. Amsterdam.
Jacomet, S., Kucan, D., Ritter, A., Suter, G., and Hagendorn, A. (2002) "Punica granatum (pomegranates) from early Roman contexts in Vindonissa (Switzerland)," *Vegetation History and Archaeobotany* 11: 79-92.
Jardé, A. (1925) *Les céreales dans l'antiquité grecque.* Paris.
Jashemski, W.F. (1974) "The Discovery of a Market-Garden Orchard at Pompeii: The Garden of the 'House of the Ship Europa'" *American Journal of Archaeology* 78: 391-404.
Jashemski, W.F. (1979a) "'The Garden of Hercules at Pompeii' (II.viii.6): The Discovery of a Commercial Flower Garden," *American Journal of Archaeology* 83: 403-411.
Jashemski, W.F. (1979b) *The Gardens of Pompeii*, 2 vols. New York.
Jashemski, W.F. (1987) "Recently excavated gardens and cultivated land of the villas at Boscoreale and Oplontis," in E.B. MacDougall, ed. (1987): 31-76.
Jashemski, W.F., Meyer, F. G., Ricciardi, M. (2002) "Plants. Evidence from Wall Paintings, Mosiacs, Sculpture, Plant Remains, Graffiti, Inscriptions, and Ancient Authors," in Jashemski and Meyer, eds. (2002): 80-180.
Jashemski, W.F. and Meyer, F. G., eds. (2002) *The Natural History of Pompeii*. Cambridge.
Johnson, H. (1971) *The World Atlas of Wine: A Complete Guide to the Wines & Spirits of the World*. London.
Jolivet, V., Pavolini, C., Tomei, M.A., and Volpe, R. eds. (2009) *Suburbium II: Il suburbio di Roma dalla fine dell'età monarchica alla nascita del sistema delle ville (V-II secolo A.C.).* Rome.
Jones, J. E., Graham, A.J., and Sackett, L.H. (1973) "An Attic country house below the cave of Pan at Vari," *Annual of the British School at Athens* 68: 355-452.
Jones, J. E. (1975) "Town and country houses of Attica in classical times," in *Thorikos and the Laurion in Archaic and Classical Times: Papers and Contributions of the Colloquium held in March 1973, at the State University of Ghent*, ed. H. Mussche. Ghent: 63-136.
Jones, M.K. (1981) "The development of crop husbandry," in Dimbleby and Jones, eds. (1981): 95-127.

Jones, M.K. (1989) "Agriculture in Roman Britain: The dynamics of change," in *Research on Roman Britain, 1960-1989,* ed. M. Todd. London: 127-34.
Jones, N. F. (2000) "Epigraphic Evidence for Farmstead Residence in Attica," *Zeitschrift für Papyrologie und Epigraphik* 133: 75-90
Jongman, W.M. (1988) *The Economy and Society of Pompeii.* Amsterdam.
Jongman, W.M. (2007a) "Gibbon was right: the decline and fall of the Roman economy," in *Crises and the Roman Empire. Proceedings of the Seventh Workshop of the International Network Impact of Empire (Nijmegen, June 20-24, 2006),* eds. O. Hekster, G. de Kleijn, D. Slootjes. Leiden: 183-199.
Jongman, W.M. (2007b) "The early Roman Empire: Consumption," in I. Morris, R. Saller and W. Scheidel eds. (2007): 592-618.
Jurišić, M. (2000) *Ancient shipwrecks of the Adriatic: maritime transport during the first and second centuries AD*. Oxford.
Kajava, M. (1998-99) "Murenae, oysters and gilt-heads. Fish for name, table, and show in ancient Rome," *Acta Classica Debrecensis* 34-35: 253-68.
Karjaka, A.V. (2008) "The Demarcation System of the Agriculture Environment of Olbia Pontike," in P. Guldager Bilde, J. Hjari, eds. *Meetings of Cultures in the Black Sea Region. Between Conflict and Coexistence*: 181-192. Aarhus.
Keay, S. ed. (1998) *The Archaeology of Early Roman Baetica*. Portsmouth, R.I.
Keay, S. and Millett, M. (2006) *Portus Romae*. Rome.
Kehoe, D.P. (1988) *The Economics of Agriculture on Roman Imperial Estates in North Africa.* Göttingen.
Kehoe, D.P. (1992) *Management and Investment on Estates in Roman Egypt during the early Empire.* Bonn.
Kehoe, D.P. (2007) "The Early Roman Empire: Production," in I. Morris, R. Saller and W. Scheidel eds. (2007): 543-69.
Kerridge, E. (1967) *The Agricultural Revolution.* London.
Kerridge, E. (1992) *The Common Fields of England*. Manchester.
Kolendo, J. (1960) "Techniques rurales. La moissonneuse antique en Gaule romaine," *Annales Économies, Sociétés, Civilisations* 15: 1099-1114.
Kolendo, J. (1980) *L'Agricoltura nell'Italia romana. Tecniche agrarie e progresso economico dalla tarda repubblica al principato.* Rome.
Kolendo, J. (1985) "Le attività agricole degli abitanti di Pompei e gli atrezzi agricoli ritrovati all'interno della città," *Opus* 4: 111-24.
Kolendo, J. (1993) "Praedia suburbana e loro redditività," in J. Carlsen, P. Ørsted, J.-E. Skydsgaard eds. (1993): 59-71.
Krasilnikoff, J.A. (2002) "Water and Farming in Classical Greece: Evidence, Models and Method," in *Ancient History Matters: Studies presented to Jens Erik Skydsgaard on his seventieth birthday,* eds. K. Ascani, V. Gabrielsen *et al*. Rome: 49-61.
Kreuz, A. (2001) "Römische Landwirtschaft – eine Entwicklung zum Besseren? Einige Aspekte aus dem Mittelgebirgsraum," in Herz and Waldherr, eds. (2001): 119-133.
Kron, G. (2000) "Roman Ley-farming," *Journal of Roman Archaeology* 2000: 277-87.
Kron, G. (2002) "Archaeozoology and the Productivity of Roman Livestock Farming," *Münstersche Beiträge zur Antike Handelsgeschichte 21, 2*: 53-73.

Kron, G. (2004a) "Roman Livestock Farming in Southern Italy: The Case Against Environmental Determinism," in *Espaces intégrés et gestion des ressources naturelles dans l'Empire romain*, eds. M. Clavel-Léveque, E. Hermon. Franche-Comté: 119-134.
Kron, G. (2004b) "A Deposit of Carbonized Hay from Oplontis and Roman Fodder Quality,"*Mouseion,* [Ser. III] 4: 275-331.
Kron, G. (2005a) "Anthropometry, Physical Anthropology, and the Reconstruction of Ancient Health, Nutrition, and Living Standards." *Historia 54*: 68-83.
Kron, G. (2005b) "The Augustan Census figures and the population of Italy," *Athenaeum* 93: 441-95.
Kron, G. (2005c) "Sustainable Roman intensive mixed farming methods: Water conservation and erosion control," in R. Bedon and E. Hermon eds. (2005) *Concepts, pratiques et enjeux environnementaux dans l'empire romain*: 285-308. Limoges.
Kron, G. (2008a) "Animal husbandry, Hunting, Fishing and Pisciculture," in Oleson, ed. (2008): 176-222.
Kron, G. (2008b) "The Much Maligned Peasant. Comparative Perspectives on the Productivity of the Small Farmer in Classical Antiquity," in Northwood and De Ligt, eds. (2008): 71-119.
Kron, G. (2008c) "Roman aquaculture: the techniques and agronomic importance of fish-farming in the light of modern research and practice," in *Vers une gestion intégrée de l'eau dans l'Empire romain*, ed. E. Hermon. Rome: 175-85.
Kuhnen, H.-P. (2003) "Les grandes entreprises agricoles de la Moselle dans l'Antiquité tardive," *Revue archéologique de Picardie* 1: 195 - 202.
Lachiver, M. (1988) *Vins, vignes et vignerons: histoire du vignoble française*. Paris.
Lafon, X. (2001) *Villa maritima. Recherches sur les villas littorales de l'Italie romaine. IIIe siècle av. J.C. - IIIe siècle ap. J.C*. Paris.
Lagardère, V. (1997) "Cépages, raisin, et vin en al-Andalus (Xe-XVe siècles)," *Médiévales* 33: 81-90.
Lagóstena, L., Bernal, D., and Aréval, A. eds. (2007) *Cetariae 2005. Salsas y Salazones de Pescado en Occidente durante la Antigüedad. Actas del Congreso Internacional (Cádiz, 7–9 de noviembre de 2005)*. Oxford.
Laiou-Thomadakis, A. (1977) *Peasant Society in the Late Byzantine Empire: A social and demographic study.* Princeton.
Laubenheimer, F. (1985) *La production des amphores en Gaule narbonnaise*. Paris.
Lauwerier, R. G. C. M. 1993. "Twenty-eight bird briskets in a pot: Roman preserved food from Nijmegen," *Archaeofauna* 2: 101-13.
Lavergne, L. de. (1855) *The rural economy of England, Scotland, and Ireland.* London.
Lawall, M. (2007) "Consuming the West in the last: Amphoras of the western Mediterranean in Athens before 86 BC," in *Old Pottery in a New Century. Innovating Perspectives on Roman Pottery Studies, Catania 22-24 April 2004*, eds. J. Lund, D. Malfitana, and J. Poblom. Catania: 265-286.
Leary, T.J. (1999) "Martial's Christmas winelist," *Greece and Rome* 46: 34-41.
Lee, W.E. (2001) "Pylos Regional Archaeological Project, Part IV: Change and the Human Landscape in a Modern Greek Village in Messenia," *Hesperia* 70: 49-98
Leguilloux, M. (2006) "Les salaisons de viande. L'apport de l'archéozoologie," in *Animali tra uomini e dei. Archeozoologica del mondo preromano. Atti del Convegno internazionale 8-9 novembre 2002*. Bologna: 139-52.

Lepetz, S. (1996) *L'animal dans la société gallo-romaine de la France du Nord.* Amiens.
Lepetz, S. (1997) "Irrigazione, drenaggio, e economia demaniale romana nelle pianure del basso Rodano: L'apporto delle ricerche geoarcheologiche nella valle dei Baux," in Coen and Quilici-Gigli, eds. (1997): 301-10.
Leveau, Ph. (1996) "The Water Mill in its Environment: Archaeology and Social History in Antiquity," *Journal of Roman Archaeology* 9: 137-57.
Livanda, A., Van der Veen, M. (2008) "Social access and dispersal of condiments in North-West Europe from the Roman to the Medieval period," *Vegetation History and Archaeobotany* 17: 201-9.
Lo Cascio, E. (2009a) *Crescita e Declino. Studi di storia dell'economia romana*. Rome.
Lo Cascio, E. (2009b) "Urbanisation as an index of demographic and economic growth," in Bowman and Wilson (2009): 87-106.
Lo Cascio, E., ed. (2006) *Innovazione tecnica progresso economico nel mondo romano, Atti degli incontri Capresi di storia della economia antica* (Capri, 13-16 aprile 2003). Bari.
Lohmann, H. (1992) "Agriculture and Country Life in Classical Attika," in B. Wells, ed. (1992): 29-57.
Lohmann, H. (1993) *Atene: Forschungen zu Siedlungs- und Wirtschafts-struktur des klassischen Attik, I-II.* Cologne.
Lowe, D. (2010) "The symbolic value of grafting in ancient Rome," *Transactions of the American Philological Association* 140: 461-88.
Lund, J. (1993) "Rhodian amphorae as evidence for the relations between late Punic Carthage and Rhodes," *Acta Hyperborea* 5: 359-375.
MacKinnon, M.R. (2004) *Production and consumption of animals in Roman Italy. Integrating the zooarchaeological and textual evidence*. Portsmouth.
MacKinnon, M.R. (2007) "State of the Discipline: Osteological Research in Classical Archaeology." *American Journal of Archaeology* 111: 473-504.
Magerstedt, A. F. (1859) *Die Viehzucht der Römer für Archäologen und wissenschaftliche gebildete Landwirthe.* Walluf.
Magerstedt, A. F. (1862) *Der Feld- Garten- und Wiesenbau der Römer*. Sondershaufen.
Marbach, A. (2004a) *Les instruments aratoires des Gaules et de Germanie Superiore. Catalogue des pièces métalliques*. Oxford.
Marbach, A. (2004b) *Recherches sur les instruments aratoires et le travail du sol en Gaule Belgique*. Oxford.
Marbach, A. (2006-7) "Essai de classement typo-technologique des araires à partir des pièces métalliques découvertes en Gaule romaine en vue de leur reconstitution," *Révue Archéologique du Centre de la France* 45-6 (http://racf.revues.org//index734.html)
Marcone, A. (1997) *Storia dell'agricoltura romana. Dal mondo arcaico all'età imperiale.* Rome.
Marcone, A. (2006) "Le innovazione nell'agricoltura romana," in E. Lo Cascio, ed. (2006): 181-95.
Margaritis, E. and Jones, M.K. (2008) "Greek and Roman Agriculture," in Oleson, ed. (2008): 158-74.
Margaropoulos, P. (1952) "Mountain range management and improvement," *Journal of Range Management* 5: 200-6.
Marshall, W. (1817) *The Review and Abstract of the County Reports to the Board of*

Agriculture. 5 vols. York.
Martin, R. (1971) *Recherches sur les agronomes Latins et leurs conceptions economiques et sociales*. Paris.
Martin-Kilcher, S. (2005) "Amphorae in the Roman West: Discussion and Research since 1989," in Eiring and Lund, eds. (2005): 263-72.
Marzano, A., and Brizzi, G. (2009) "Costly display or economic investment? A quantitative approach to the study of marine aquaculture," *Journal of Roman Archaeology* 22: 215-30.
Marzano, A. (2007) Roman Villas in Central Italy. A Social and Economic History. Leiden.
Massendari, J. (2007) "Les agronomes latins et l'archéologie agraire. Stabulation et parcage du bétail," *Pallas* 75: 59-76.
Mattingly, D.J. (1988a) "The Olive Boom. Oil Surpluses, Wealth and Power in Roman Tripolitania," *Libyan Studies* 19: 21-41.
Mattingly, D.J. (1988b) "Oil for Export? A Comparison of Libyan, Spanish and Tunisian Olive Oil Production in the Roman Empire," *Journal of Roman Archaeology* 1: 33-56.
Mattingly, D.J. (1993a) "Maximum figures and Maximizing Strategies of Oil Production? Further Thoughts on the Processing Capacity of Roman Olive Presses," in Amouretti, M.C. and Brun, J.-P., eds. (1993): 483-498.
Mattingly, D.J. (1993b) "Regional Variation in Roman Oleoculture: Some Problems of Comparability, in J. Carlsen, P. Ørsted, J.-E. Skydsgaard eds. (1993): 91-106.
Mattingly, D.J. (1996) "First fruit? The olive in the Roman world," in Shipley and Salmon, eds. (1996): 213-53.
Mattingly, D.J. (2009) "Olive oil (and wine?) production in N Tunisia," *Journal of Roman Archaeology* 22: 715-20.
May, J.M. (1953) *The Ecology of Malnutrition in Five Countries of Eastern and Central Europe (East Germany, Poland, Yugoslavia, Albania, Greece)* (New York) 233- 77.
McDonald, W.A., Rapp, G. (1972) *The Minnesota Messenia expedition: reconstructing a Bronze Age regional environment*. Minneapolis.
Mee, C., and Forbes, H.A. (1997) *A Rough and Rocky Place: The Landscape and Settlement History of the Methana Penninsula, Greece.* Liverpool.
Meeks, D. and Garcia, D. (1997) *Techniques et économie antiques et médiévales: le temps de l'innovation. Colloque international (C.N.R.S.) Aix-en-Provence 21-23 Mai 1996*. Paris.
Manning, J.G. 2003. *Land and power in Ptolemaic Egypt: the structure of land tenure*. Cambridge and New York: Cambridge University Press.
Miller, J. I. (1969) *The Spice Trade of the Roman Empire, 29 BC to AD 641*. Oxford.
Miller, N.F., and Gleason, K.L., eds. (2002) *The Archaeology of Garden and Field*. Philadelphia.
Monsieur, P. 2007. "Amphora burials and burials with amphorae. On the reuse of amphorae in the northern necropolis of Potentia (Porto Recanati, Marche)," *TRAC 2006*. Oxford: 133-49.
Moreno, A. (2007) *Feeding the Democracy. The Athenian Grain Supply in the Fifth and Fourth Centuries B.C.* Oxford.
Moreno García, J.C. (2005) "Introduction: nouvelles recherches sur l'agriculture institutionelle et domestique en Égypte ancienne dans le contexte des sociétés antiques,"

in *L'agriculture institutionelle en Égypte ancienne: état du question et perspectives interdisciplinaires,* ed. J.C. Moreno García. Villeneuve d'Asq: 11-78.
Morley, N. (1996) *Metropolis and Hinterland: the city of Rome and the Italian economy 200 B.C. – A.D. 200.* Cambridge.
Morris, I., Saller, R., and Scheidel, W. eds. (2007) *The Cambridge Economic History of the Greco-Roman World.* Cambridge.
Mudge, K. et al. (2009). "A History of Grafting," *Horticultural Reviews* 35: 437–94.
Niquet, H. (2000). "The Ideal of the Senatorial Agriculturalist and Reality During the Roman Republic and Empire," in *Double Standards in the Ancient and Medieval World*, ed. K. Pollman. Göttingen**:** 121-133.
Northwood, S., and de Ligt, L., eds. (2008) *People, Land, and Politics: Demographic Developments and the Transformation of Roman Italy 300 BC - AD 14*. Leiden.
Oddy, D.J. (1970) *The Working-Class Diet 1886-1914* (diss. London)
Oder, E. 1890-3. "Beitrage zur Geschichte der Landwirthschaft bei den Griechen," *Rheinisches Museum* 45: 58-99; 212-22; *Rheinisches Museum* 48: 1-40.
Oleson, J.P. (1984) *Greek and Roman mechanical water-lifting devices*. Toronto.
Oleson, J.P. (1988) "The technology of Roman harbours," *International Journal of Nautical Archaeology* 17: 147-58.
Oleson, J. P., ed. (2008) *The Oxford Handbook of Engineering and Technology in the Classical World.* New York.
Oleson, J.P. (forthcoming) *Humayma Excavation Project, 1: Resources, History, and the Water Supply System*. Boston.
Oleson, J.P., Brandon, C., Cramer, S.M., Cucitore, R., Gotti, E., and Hohlfelder, R.L. (2004) "The ROMACONS project: a contribution to the historical and engineering analysis of hydraulic concrete in Roman maritime structures," *International Journal of Nautical Archaeology* 33: 199-229.
Oleson, J.P., Bottalicio, L., Brandon, C., Cucitore, R., Gotti, E., and Hohlfelder, R.L. (2006) "Reproducing a Roman maritime structure with Vitruvian pozzolanic concrete," *Journal of Roman Archaeology* 19: 29-52.
Oleson, J.P., Brandon, C., and Hohlfelder, R.L. (2008). "The Roman Maritime Concrete Study (ROMACONS): Activities to 2007," pp. 325-29 in J. P. Delgado, ed., "Nautical and Maritime Archaeology, 2006-2007 Seasons," *American Journal of Archaeology* 112: 307-35.
Olive, C. and S. Deschler-Erb (1999) "Poulets de grain et rôtis du cerf. Produits de luxe pour les villes Romaines," *Archäologie der Schweiz* 22: 35-8.
Ortalli, J. (2006) "Parva luxuria. Qualità residenziali dell'insediamento rustico minore norditalico," in *Vivere in villa. Le qualità delle residenze agresti in età romana. Atti del convegno, Ferrara, gennaio 2003.* Florence: 261-83.
Osborne, R. (1987) *The Classical Landscape with Figures.* London.
Osborne, R. (1992b) "Classical Greek gardens: between farm and paradise," in *Garden History: Issues approaches, methods*, ed. J.D. Hunt. Washington, D.C.: 372-91.
Panella, C. (2001) "Le amfore romane di età imperiale del Mediterraneo occidenale," in *Céramiques héllenistiques et romaines*, III, eds. P. Léveque, J.-P. Morel. Franche-Comté: 177-275.
Papadopoulos, J.K. and Stavros A. Paspalas, S.A. (1999) "Mendaian as Chalkidian Wine," *Hesperia* 68: 161-188.

Papathomas, A. (2006) " Zu den Luxusspeisen und -getränken in griechischen Papyri," *Zeitschrift für Papyrologie und Epigraphik* 158: 193-200
Parker, A. J. (1990) “The wines of Roman Italy,” *Journal of Roman Archaeology* 3: 325-31.
Parker, A. J. (1992) *Ancient Shipwrecks of the Mediterranean and the Western Provinces*. Oxford.
Pasquinucci, M. (2002) “L’allevamento,” in *Storia dell’agricoltura italiana I.2 Italia romana*, eds. G. Forni and A. Marcone. Florence: 157-224.
Pasquinucci, M. and Weski, T. eds. (2004) *Close encounters: Sea- and riverborne trade, ports and hinterlands, ship construction and navigation in antiquity*. Oxford.
Patterson, H., ed. (2004) *Bridging the Tiber: approaches to regional archaeology in the middle Tiber valley*. London.
Patterson, H., et al. (2000) "The Tiber Valley Project: the Tiber and Rome through two millenia." *Antiquity* 74: 395-403.
Patterson, H. and Millett, M. (1998) "The Tiber Valley Project." *Papers of the British School at Rome* 66: 1-20.
Peacock, D.P.S. (1974) "Amphorae and the Baetican Fish Industry," *Antiquaries Journal* 54: 232-43.
Peacock D.P.S., and Williams, D.F. (1986) *Amphorae and the Roman Economy.* London.
Peacock D.P.S., and Williams, D.F. (2005) "Vesuvius and Campanian Dressel 2-4 Amphorae," in *Terra marique. Studies in Art History and Marine Archaeology in Honor of Anna Marguerite McCann*, ed. J. Pollini. Oxford: 140-8.
Pease, A. S. (1933). “Notes on Ancient Grafting.” *Transactions of the American Philological Association* 64: 66–76.
Pecirka, D. (1970a) "Excavations of Farms and Farmhouses in the Chora of Chersonesus in the Crimea," *Eirene* 8 (1970) 123-74.
Pecirka, D. (1970b) “Country Estates of the Polis of Chersonnesos,” in *Ricerche storiche ed economiche in memoria di Corrado Barbagallo*, ed. L.D. Rosa. Naples: 459-77.
Pepelasis, A.A., Thompson, K. 1960. "Agriculture in a Restrictive Environment: The Case of Greece,"*Economic Geography* 36: 145-157.
Pergola, Ph., Santangeli Valenzani, R., and Volpe, R., eds. (2003) *Suburbium. Il suburbio di Roma dalla crisis del sistema delle ville a Gregorio Magno*. Rome.
Pensavento Mattioli, S., ed. (1998) *Bonifiche e drenaggi con anfore in epoca romana: iaspetti tecnici e topografici*. Padua.
Peters, J. (1998) *Römische Tierhaltung und Tierzucht. Eine Synthese aus archäozoologischer Untersuchung und schriftlich-bildlicher Überlieferung.* Rahden.
Pleket, H. W. (1990) *Die Landwirtschaft in der römischen Kaiserzeit*, in *Europäische Wirtschafts- und Sozialgeschichte in der Römischen Kaiserzeit*, I, ed. F. Wittinghoff, Stuttgart.
Pleket, H. W. (1993) "Agriculture in the Roman empire in comparative perspective," in Sancisi-Weerdenburg (1993): 214-37.
Pöhlmann, R. (1884) *Die Überbevölkerung der antiken Großstàdte im Zusammenhange mit der Gesamtentwicklung städtischer Civilisation dargestellt.* Leipzig.
Pons Pujol, L. (2006) "L'importation de l'huile de Bétique en Tingitane et l'export des salaisons de Tingitane (I-IIIe siècles ap. J.-C.)," *Cahiers Glotz* 17: 61-77.
Pons Pujol, L. (2007) "Contenidores para la exportación de las salazones Tingitanas en el

alto imperio," in Lagóstena, Bernal and Aréval, eds. (2007): 453-61.
Pons Pujol, L. (2009) *La Economía de la Mauretania Tingitana (s. I-III d.C.). Aceite, vino y salazones*. Barcelona.
Ponsich, M. (1974-1991) *Implantation rurale antique dans sur les Bas-Guadalquivir*, 4 vols. Madrid-Paris.
Ponsich, M. (1988) *Aceite de oliva y salazones de pescado. Factores geo-económicos de Bética y Tingitania*. Madrid.
Ponsich, M. (1998) "The rural economy of Western Baetica," in Keay, ed. (1998): 171-82.
Price, S., and Nixon, L. (2005) "Ancient Greek agricultural terraces: evidence from texts and archaeological survey," *American Journal of Archaeology* 10: 665-94.
Prieto, A. (2008) "Les guerres de l'eau dans l'Hispanie romain," in Hermon ed. (2008): 77-88.
Pritchard, R.T.(1972) "Some aspects of First Century Sicilian Agriculture," *Historia* 21: 646-660.
Provost, M. (1993) *Le Val de Loire dans l'Antiquité*. Paris.
Purcell, N. "Wine and wealth in ancient Italy," *Journal of Roman Studies* 75 (1985): 1-19.
Purcell, N. (1987) "Town in country and country in town," in *Ancient Roman Villa Gardens*, ed. E.B. MacDougall. Washington, D.C.: 187-203.
Purcell, N. (1995) "The Roman villa and the landscape of production," in *Urban Society in Roman Italy*, eds. T.J. Cornell and K. Lomas. London: 151-79.
Quilici-Gigli, S. (1979) "La villa nel suburbio romano: Problemi di studio e di inquadramento storico-topografico," *Archeologia classica* 31: 309-17.
Quilici-Gigli, S. (1989) "Paesaggi storici dell'agro falisco: I prata di Corchiano," *Opuscula Romana* 17: 123-35.
Quilici-Gigli, S. (1992) "Opere di bonifica in relazione a tracciati viari," in *Tecnica stradale romana. Rome*
Quilici-Gigli, S. (1994) "The Changing Landscape of the Roman Campagna: Lo sfruttamento del territorio in età imperiale," in Carlsen, Ørsted, and Skydsgaard, eds. (1994): 135-43.
Quilici-Gigli, S. (2008) "The management of the water regime in agrarian contexts in Central Italy," in Hermon, ed. (2008): 217-28.
Quilici, L., and Quilici Gigli, S., eds. (1995) *Interventi di bonifica agraria nell'Italia romana*. Rome.
Quilici, L. (2008) "Land transport, part 1: roads and bridges," in Oleson, ed. (2008): 551-79.
Rackham, O. (1983) "Observations on the historical ecology of Boeotia," *Annual of the British School at Athens* 78: 291-351.
Rackham, O. (1996) "Ecology and pseudo-ecology: the example of ancient Greece," in Shipley and Salmon, eds. (1996): 16-44.
Raepsaet, G. (1987) "Aspects de l'organisation du commerce de la céramique sigillée dans le Nord de la Gaule au IIe siècle de notre ère, 1. Les données matérielles," *Münstersche Beiträge zur antiken Handelsgeschichte* 6: 1-29.
Raepsaet, G. (2008) "Land Transport, Part 2: Riding, Harnesses, and Vehicles," in J.P. Oleson, ed. (2008): 580-605.
Rathbone, D.W. (1983) "Italian wines in Roman Egypt," *Opus* 2: 81-98.

Rathbone, D.W. (1991) *Economic rationalism and rural society in third-century A.D. Egypt. The Heroninos archive and the Appianus estate*. Cambridge.
Rathbone, D.W. (2007). "Roman Egypt," in W. Scheidel, I. Morris, R. P. Saller, eds. (2007): 698-719.
Rathbone, D.W. (2008) "Poor peasants and silent sherds," in Northwood and de Ligt, eds. (2008): 305-332.
Rathbone, D.W. (2010) "Review of Clarysse & Thompson, Counting the people in Hellenistic Egypt 1," *Journal of Hellenic Studies* 127: 186-7.
Rauh, N.K. (1999) "Rhodes, Rome, and the eastern Mediterranean wine trade, 166-88 B.C.," in *Hellenistic Rhodes. Politics, culture, and society*, eds. V. Gabrielsen *et al*. Aarhus: 162-86.
Rauh, N.K. (2003) *Mercants, sailors and pirates in the Roman World*. Stroud, Gloucestershire.
Rauh, N.K. (2005) "Pirated knock-offs: Cilician imitations of internationally traded amphoras," in Eiring and Lund, eds. (2005): 329-36.
Remesal Rodriguez, J. (1998) "Baetican olive oil and the Roman economy," in Keay, ed. (1998): 183-199.
Remesal Rodriguez, J. (1999) "Politica e regimi alimentari nel principio di Augusto," in Vera, ed. (1999): 247-71.
Remesal Rodriguez, J. (2001) "Politik und Landwirtschaft im Imperium Romanum am Beispiel der Baetica," in Herz and Waldherr, eds. (2001): 235-255.
Renfrew, C., and Wagstaff, M. (1982) *Melos. An Island Polity: The Archaeology of Exploitation in Melos.* Cambridge.
Revilla, V. (2007) "Production céramique, systèmes agraires, et peuplement dans le térritoire *Tarraco*," in *Pottery Workshops and Agricultural Productions*. Girona: 83-113.
Reynolds, P.J. (1979) *Iron Age Farm*. London.
Reynolds, P.J. (1995) "Rural Life and Farming," in *The Celtic World*, ed. M. Green. London: 176-209.
Rickman, G. (1971) *Roman Granaries and Store Buildings*. Cambridge.
Rickman, G. (1980) *The Corn Supply of Ancient Rome.* Oxford.
Rickman, G. (1988) "The archaeology and history of Roman ports," *International Journal of Nautical Archaeology* 17: 257-67.
Rinkewitz, W. (1984) *Pastio Villatica. Untersuchungen zur intensiven Tierhaltung in der römischen Landwirtschaft.* Frankfurt.
Robertson, G.P., and Vitousek, P.M. (2009) "Nitrogen in Agriculture: Balancing the Cost of an Essential Resource," *Annual Review of Environment and Resources 34*: 97-125.
Rodríguez Almeida, E. (1984) *Il Monte Testaccio: ambiente, storia, materiali.* Rome.
Romano, P., and Suzzi, G. (1993) "Sulfur Dioxide and Wine Micro-organisms," in *Wine Microbiology and Biotechnology*, ed. G.E. Fleet. London: 373-94.
Rosivach, V.J. (1994) *The system of public sacrifice in fourth-century Athens*. Atlanta.
Rossi, P. (1994) "Sulla geografia agraria in età romana: una conferma storica al modello di von Thünen," *Aufidus* 23: 57-66.
Rossiter, J.J. (1978) *Roman Farm Buildings in Italy*. Oxford.
Rossiter, J.J. (1981) "Wine and Oil Processing at Roman Farms in Italy," *Phoenix* 35: 345-361.
Rostovzeff, M.I. (1967) *A large estate in Egypt in the third century B.C.: a study in*

economic history. Rome.
Rowlandson, J. (1996) *Landowners and Tenants in Roman Egypt. The Social Relations of Agriculture in the Oxyrhynchite Nome.* Oxford.
Rougé, J. (1966) *Recherches sur l'organisation du commerce maritime en Méditerranée dans l'empire romaine*. Paris.
Roy, J.R. (1999) "The Economies of Arkadia," in *Defining Ancient Arkadia. Symposium, April 1-4, 1998*. eds. J.R. Roy, T.H. Nielsen. Copenhagen: 320-81.
Russell, E.J. (1942) Rothamsted and Its Experiment Station," *Agricultural History* 16: 161-183.
Sadori, L., et al. (2009) "The introduction and diffusion of the peach in ancient Italy," in *Plants and Culture: seeds of the cultural heritage of Europe*: 45-61. Bari.
Safrai, Z. (1994) *The Economy of Roman Palestine.* London.
Sahrhage, D. (2002) *Die Schätze Neptuns. Eine Kulturgeschichte der Fischerei im römischen Reich.* Frankfurt am Main.
Sallares, R.M. (1991) *The Ecology of the Ancient Greek World*. Cambridge.
Saltini, A. (2002) "Il sapere agronomico. Empirismo e sapere scientifico. Nasce a Roma la scienza agronomica," in Forni and Marcone, eds. (2002): 353-82.
Salviat, F. (1986) "Le vin de Thasos, vin, amphores, et sources écrites," in *Recherches sur les amphores Grecques*: 145-96. Athens-Paris.
Sancisi-Weerdenburg, H. ed. (1993) *De Agricultura. In Memoriam Pieter Willem de Neeve (1945-1990).* Amsterdam.
Sanquer, R. and Galliou, P. (1970) "Garum, sel et salaisons en Armorique gallo-romaine," *Gallia* 30: 199-223.
Santillo Frizell, B. and Klynne, A. (2005) *Roman villas around the* Urbs. *Interaction with landscape and environment. Proceedings of a conference held at the Swedish Institute in Rome, September 17–18, 2004.* Rome.
Saprykin, S.J. (1995) *Ancient Farms and Land-Plots on the Khora of Khersonesos Taurike: Research in the Herakleian Penninsula.* Amsterdam.
Scheidel, W. (1994) *Grundpacht und Lohnarbeit in der Landwirtschaft des römischen Italien.* Stuttgart.
Scheidel, W. (2009) "In search of Roman economic growth," *Journal of Roman Archaeology* 22: 71-82.
Schnebel, M. (1925) *Die Landwirtschaft im hellenistischen Ägypten,* I-II, Munich.
Semple, E.C. (1922) "The Influence of Geographical Conditions on Ancient Mediterranean Stock-Raising," *Annals of the American Association of Geographers* 12: 3-28.
Shipley, G. and Salmon, J. eds. *Human landscapes in classical antiquity. Environment and culture*. London-New York.
Silver, M. (2009), "Historical otherness, the Roman bazaar, and primitivism: P.F. Bang on the Roman Economy," *Journal of Roman Archaeology* 22: 648-43.
Sirago, V.A. (1995) *Storia Agraria Romana,* 2 vols. Naples.
Slane, K.W. (2005) "Amphoras - used and reused - at Corinth," in Eiring and Lund, eds. (2005): 361-9.
Slicher Van Bath, B. H. (1963) *The Agrarian History of Western Europe AD 500-1850.* London.
Spurr, M. S. (1986) *Arable Cultivation in Roman Italy c.200 B.C.- c.A.D. 100.* London.

Sylvester, K.M. 2009. "Ecological Frontiers on the Grasslands of Kansas: Changes in Farm Scale and Crop Diversity," *Journal of Economic History* 69: 1041-62.
Tchernia, A. (1986) *Le vin de l'Italie romaine: essai d'histoire économique d'après les amphores.* Rome.
Teall, J.L. (1971) "The Byzantine Agricultural Tradition," *Dumbarton Oaks Papers* 25: 33-59
Thomas, R., Wilson, A. (1994) "Water supply for Roman farms in Latium and South Etruria," *Papers of the British School at Rome* 62: 139-96.
Thüry, G. E., Walter, J. (1997) *Condimenta: Gewürzpflanzen in Koch- und Backrezepten aus der römischen Antike : Begleitbuch zur Pflanzenschau « Altrömische Gewürze »*. Vienna.
Thurmond, D. (2006) *A Handbook of Ancient Food Processing. For Her Bounty No Winter*. Leiden.
Tomber, R. (2005a) "Amphorae from the Red Sea and their contribution to the interpretation of Roman trade beyond the Empire," in Eiring and Lund, eds. (2005): 393-402.
Tomber, R. (2005b) "Trade relations in the eastern Mediterranean and beyond: the Egyptian-Indian connection," in M.B. Briese, L.E. Vaag (eds.), *Trade Relations in the Eastern Mediterranean from the Late Hellenistic Period to Late Antiquity: The Ceramic Evidence*: 221-33. Odense.
Tomber, R. (2008) *Indo-Roman Trade: From Pots to Pepper*. London.
Toneatto, L. (1994-5) *Codices artes mensuriae. I manoscritti degli antichi opusculi latini d'agrimensura (V-XIX sec.)*, I-III. Spoleto.
Tremoleda i Trilla, J. (2007) "Les installacions productives d'àmfores tarraconenses," in *La Producció i el commerç de les àmfores de la Provincia Hispania Tarraconensis. Homenatge a Ricard Pascual i Guasch*, eds. A. López Mullor, X. Aquilié Abadias. Barcelona: 113-50.
Uggeri, G. (1969) "*Kleroi* antici e bonifica classica nella *chora* di Metaponto," *Parola di Passato* 24: 51-71.
Uggeri, G. (1987) "La navigazione interna della Cisalpina in età romana,"*Antichità Alto-Adriatiche* 19: 305-54.
Valenti, M. (2003) *Ager Tusculanus. Forma Italiae 43*. Florence.
Van der Mersch, C. (1994) *Vins et amphores de Grand Grèce et de Sicile, IVe - IIIe siècles av. J.-C.* Naples.
Van der Mersch, C. (1996) "Vigne, vin et économie dans l'Italie du Sud grecque à l'époque archaïque," *Ostraka* 5: 155-185.
Van der Mersch, C. (2001) "Aux sources du vin romain dans le Latium et la Campania à l'époque médio-républicaine," *Ostraka* 10: 157-206.
Van der Veen, M. (1998a) "A life of luxury in the desert? The food and fodder supply to Mons Claudianus," *Journal of Roman Archaeology* 11: 101-116.
Van der Veen, M. (1998b) "Gardens in the desert," in *Life on the fringe. Living in the southern Egyptian deserts during the Roman and early-Byzantine periods. Proceedings of a colloquium held in Cairo, 9-12 December 1996)*: 221-42. Leiden.
Van der Veen, M. (2001) "Chapter 8. The botanical evidence," in *Mons Claudianus. Survey and excavation 1987-1993, II. Excavations: Part 1*, eds. V.A. Maxfield and D.P.S. Peacock. Paris: 174-222.

Van der Veen, M., and Wasylikowa, K. (2004) "An archaeobotanical contribution to the history of watermelon: *Citrullus lanatus* (Thunb.) ..." *Vegetation History and Archaeobotany* 13: 213-7.
Vera, D., ed. (1999), *Demografia, Sistemi Agrari, Regimi Alimentari nel Mondo Antico. Atti del Convegno Internazionale di Studi (Parma 17-19 ottobre 1997).* Bari.
Wagstaff, M. (2002) "The Modern Era," in *Continuity and Change in a Greek Rural Landscape. The Laconia Survey I: Methodology and Interpretation*, eds. Cavanaugh, W. Catling, R.W.V., Crouwel, J., and Shipley, G. London: 402-20.
Wallace-Hadrill, A. (2008) *The Roman Cultural Revolution.* Cambridge.
Ward-Perkins, B. (2005) *The Fall of Rome and the End of Civilization.* Oxford.
Warringer, D. (1939) *Economics of Peasant Farming.* 2nd edn. Oxford.
Webber, R. (1972) *Market Gardening. The History of Commercial Flower, Fruit and Vegetable Growing*. London.
Wells, B. ed. (1992) *Agriculture in Ancient Greece*. Stockholm.
Werner, P., and Holmes, F.L. (2002) "Justus Liebig and the Plant Physiologists," *Journal of the History of Biology* 35: 421-441.
Wickander, Ö. (2008) "Sources of Energy and Exploitation of Power," in Oleson, ed. (2008): 136-57.
Whitbread, I.K. (1995) *Greek Transport Amphorae: A Petrological and Archaeological Study*. Exeter.
White, K.D. (1967) *Agricultural Implements of the Roman World*. Cambridge.
White, K.D. (1970a) *Roman Farming.* London.
White, K.D. (1970b) "Fallowing, Crop Rotation, and Crop Yields in Roman Times," *Agricultural History* 44: 281-90.
Wickson, E.J. (1891) *The California fruits and how to grow them*. San Francisco.
Will E. L. (1982) "Greco-Italic amphoras," *Hesperia* 51: 338-356.
Will E. L. (1991) "The Mediterranean shipping amphoras from Arikamedu," in Begley and de Puma, eds. (1991): 151-6.
Will E. L. (1997) "Shipping amphoras as evidence of economic Romanization in Athens," in *The Romanization of Athens: Proceedings of an international conference held at Lincoln, Nebraska (April, 1996)*, eds. M.C. Hoff and S.I. Rotroff. Oxford: 117-36.
Wilson, A.I. (1999) "Deliveries *extra urbem*: aqueducts and the countryside," *Journal of Roman Archaeology* 12: 314-29.
Wilson, A.I. (2002) "Machines, Power and the Ancient Economy," *Journal of Roman Studies* 92, 1-32.
Wilson, A.I. (2006) "Fishy business: Roman exploitation of marine resources," *JRA* 19: 525–37.
Wilson, A.I. (2007) "Fish-salting workshops in Sabratha," in Lagóstena, Bernal and Aréval, eds. (2007): 173-81.
Wilson, A.I. (2008a) "Machines in Greek and Roman technology," in Oleson, ed. (2008): 337-66.
Wilson, A.I. (2008b) "Large-scale Manufacturing, Standardization, and Trade," in Oleson, ed. (2008): 393-417.
Wilson, A.I. (2009a) "Villas, horticulture and irrigation infrastructure in the Tiber Valley," in F. Coarelli and H. Patterson, eds. *Mercator Placidissimus: The Tiber \ Valley in Antiquity. New research in the upper and middle river valley*: 731-68. Rome.

Wilson, A.I. (2009b) "Approaches to quantifying Roman trade," in Wilson and Bowman, eds. (2009): 213-49.
Wilson, A.I., and Bowman, A. eds. (2009) *Quantifying the Roman Economy. Methods and Problems*. Oxford.
Witcher, R.E. (2005) "The extended metropolis: *urbs*, *suburbium* and population," *Journal of Roman Archaeology* 18: 120-38
Witcher, R.E. (2006) "Settlement and society in early imperial Etruria," *Journal of Roman Studies* 96: 88-123
Woolf, G. (1998) *Becoming Roman*. Cambridge.
Wordie, J.R. (1974) "Social Change on the Leveson-Gower Estates, 1714-1832," *The Economic History Review*, N.S. 27: 593-609.
Yeo, C.A. (1946) "Land and Sea Tranportation in Imperial Italy," *Transactions of the American Philological Association* 77: 221-44.
Yeo, C.A. (1948) "The Overgrazing of ranch lands in Roman Italy," *Transactions of the American Philological Association* 79: 275-307.
Yntema, D. (1993) "Greeks, natives and farmsteads in South-eastern Italy," in Sancisi-Weerdenburg, ed. (1993): 78-97.
Young, G.K. (2001) *Rome's Eastern Trade: International Commerce and Imperial Policy 31BC - 305AD*. London-New York.

