A systematic method for estimating the populations of Greek and Roman settlements

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The last few years have seen a growing interest in the urbanism of the Greek and Roman world.[1] This has led to a consensus of sorts about some of its vital statistics, such as the sizes of the populations of the most important settlements and the size of the overall urban population, the urbanization rate (i.e., the share of individuals that lived in urban, rather than rural, contexts), and the total population.[2] A good example comes from W. Scheidel in the *Cambridge economic history of the Greco-Roman world*.[3] According to him, it is likely that *c.*1.5 million people lived in the 5 largest cities of the Greco-Roman world by the 2nd c. A.D. These included Rome, which is usually agreed to have had a population of about 1 million; Alexandria, which might have had *c.*500,000; Antioch, which could have had at least 150,000; and Carthage and Ephesus (Scheidel does not give explicit figures for those). Although there must have been a few more cities of about the same size, most of the rest were reasonably small with on average no more than a few thousand inhabitants.[4] Accordingly, Scheidel suggests that the overall urban population of the Greco-Roman world was between 7 and 9 million, and that the urbanization rate would have to have been between 10% and 15% to agree with his estimate for the total population of between 59 and 72 million.[5]

Although the bare outlines of this summary are almost certainly correct, there is surprisingly little evidence for many of these statements.[6] There is relatively good evidence for the estimates for Rome, Alexandria and perhaps Antioch, but there is little information about the rest of the settlements. As a result, it has been virtually impossible to discuss the size of most settlements and the size of the overall urban population, the urbanization rate or the total population with much confidence. Here we will review earlier attempts to estimate the populations of ancient settlements based on various forms of textual and archaeological evidence and summarise more recent attempts to estimate the populations of such settlements by measuring their inhabited areas and multiplying these by ranges of

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1 A. K. Bowman and A. I. Wilson (edd.), *Quantifying the Roman economy* (Oxford 2009); iid. (edd.), *Settlement, urbanization, and population* (Oxford 2011); P. Erdkamp, "Urbanism," in W. Scheidel (ed.), *The Cambridge companion to the Roman economy* (Cambridge 2012) 241-65; M. H. Hansen, *The shotgun method: the demography of the ancient Greek city-state culture* (Columbia, MO 2006); id., "An update on *The shotgun method*," *GRBS* 48 (2008) 259-86; J. W. Hanson, "The urban system of Roman Asia Minor and wider connectivity," in Bowman and Wilson ibid. (2011) 229-75; id., *An urban geography of the Roman world, 100 B.C. to A.D. 300* (Oxford 2016); D. Kennedy, "Demography, the population of Syria, and the census of Q. Aemilius Secundus," *Levant* 38 (2006) 109-24; W. Scheidel, "Demographic and economic development in the ancient Mediterranean world," *J. Institutional & Theoretical Economics* 180.4 (2004) 743-57; id., "Demography," in W. Scheidel, I. Morris and R. P. Saller (edd.), *The Cambridge economic history of the Greco-Roman world* (Cambridge 2007) 38-86; A. I. Wilson, "City sizes and urbanisation in the Roman Empire," in Bowman and Wilson ibid. (2011) 161-95.

2 Kennedy (supra n.1) 109.

3 Scheidel 2007 (supra n.1) 78.

4 Ibid. 80.

5 Scheidel 2004 (supra n.1) 747; id. 2007 (supra n.1) 79.

6 Hanson 2016 (supra n.1).

population densities. We then discuss current attempts to model the relationship between the inhabited areas, population densities, and populations of modern settlements in mathematical form, before exploring whether it is possible to detect a similar relationship in ancient settlements and, if so, whether it can be used to refine the ranges of population densities used by previous scholars. To do this, we have compiled new evidence for the numbers of residential structures in a sample of over 50 sites, suggested a figure for their average number of inhabitants, estimated their populations, and divided these figures by the area that was studied to generate new estimates of their population densities. The results suggest that there is indeed a strong relationship between the inhabited areas, population densities, and populations of these sites, one which is consistent with the models referred to above. This relationship can be expressed by a simple equation, which allows us to predict the populations of some of the most important settlements with remarkable accuracy and precision. This provides us with a new tool that can be used to estimate the populations of the other settlements in the ancient world so long as we have evidence for their inhabited areas. This enables us to arrive at a new estimate for the overall urban population of the Greek and Roman world, allowing us to make some new suggestions about its urbanization rate and total population.

The most common forms of evidence that have been used to estimate the populations of ancient settlements are textual sources, inscriptions and papyri. These are notoriously difficult to use because they usually refer only to specific groups, such as the numbers of individuals who served on councils or called themselves citizens, as well as those who received various kinds of hand-outs or could be taxed or raised as an army. As a result, it is nearly always necessary to extrapolate from the figures in the sources to the total population. There are recurrent issues concerning the exact ratio of men to women and children, as well as the share of slaves, foreigners and other groups. The exercise is also complicated by the fact that many of the numbers refer to both the settlement and its immediate hinterland or surrounding countryside.

Alternative forms of evidence that have been used to estimate the populations of ancient settlements include a number of archaeological proxies, such as the numbers of beneficiaries of different kinds of euergetism; the numbers of individuals interred in cemeteries; the numbers of seats in entertainment structures; and the amount of water supplied by aqueducts. Many of these forms have also been shown to be problematic.[7] The number of beneficiaries of different kinds of euergetism seems to have had little to do with the size of the total population and is likely to have been conditioned by other factors, such as the expense that the benefactor could tolerate. It is also difficult to use the numbers interred in cemeteries because there is substantial variation in the number of individuals who were buried rather than cremated, as well as in the presence or absence of grave goods, with the result that it is very difficult to extrapolate from known graves to the total population.[8] In the case of entertainment structures, many were designed to accommodate both

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7 R. P. Duncan-Jones, "Human numbers in towns and town-organisations of the Roman Empire: the evidence of gifts," *Historia* 13 (1964) 199-208; id., "Aqueduct capacity and city populations," *Lib. Stud.* 9 (1977-78) 51; id., *The economy of the Roman Empire: quantitative studies* (Cambridge 1982) 261-62; J. A. Lloyd and P. R. Lewis, "Water supply and urban population in Roman Cyrenaica," *Lib. Stud.* 8 (1976-77) 35-40; Wilson 2011 (supra n.1) 170.

8 S. R. F. Price, "Establishing ancient Greek populations: the evidence of field survey," in Bowman and Wilson 2011 (supra n.1) 17-35.

the residents of the immediate settlement and those of its nearest neighbours (as illustrated by the riot between the inhabitants of Pompeii and Nuceria in A.D. 59 [Tac., *Ann.* 14.17]). Finally, the amount of water supplied by aqueducts must have varied enormously, depending on how much of it was used for non-domestic *versus* domestic uses and how much was obtained through other means (e.g., wells and cisterns).[9]

Over the last decade increasing attention has been paid to estimating populations by measuring inhabited areas and multiplying the results by a range of population densities. Although this method was first suggested by J. Beloch in 1886 and has been used by a number of scholars over the last 130 years, it has recently come to the fore due to the increasing amount of information about inhabited areas generated by surface surveys, aerial photography and satellite imagery.[10] M. H. Hansen used this method to estimate the populations of over 200 *poleis* in the Greek world at or around the 4th c. B.C., which led to suggestions about the overall urban population, urbanization rate, and total population.[11] A. I. Wilson also used this method to estimate the populations of various sites in the 2nd c. A.D., which led him to suggest that the overall urban population was about 10 million.[12] Most recently, J. W. Hanson used this method to estimate the populations of 885 cities in *c.*A.D. 150.[13] This suggested that the overall urban population must have been at least 9.8 million, implying that either the urbanization rate or the total population must have been much larger than previously thought.

The strength of the 'area x density method' is that it enables one to control and manipulate our estimates of the population of each settlement. It allows one to establish a range of figures for the population densities of each settlement, which can then be used to explore the upper and lower limits of what might have been possible in terms of human numbers.[14] Another strength is that it allows one to keep separate the evidence for the inhabited areas of each settlement and the evidence for the range of population densities applied to it. The evidence for the inhabited areas of each settlement, which is directly derived from maps, plans and satellite images, can be subjected to verification by others. As it is easy to obtain, it can be generated from the existing stock of information, expanded with new evidence, or updated. In a similar fashion, it is possible to base the range of population densities on whatever evidence is available, and this can be compared with what is known about settlements from other civilizations to judge its appropriateness. Importantly, this method allows one to estimate the populations of a much larger number of sites than is feasible using other methods. As Wilson has pointed out, although the 'area x density method' is not perfect, it is the *only* method that allows one to correct the existing bias towards the most well-known sites and for which there is sufficient evidence for a large enough sample to allow one to explore overall patterns and trends, such as the size of the overall urban population, the urbanization rate, and the total population.

The weakness of this method, however, is that there has been virtually no evidence for how concentrated the occupation of settlements was. Thus it has often been necessary to use

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9 Duncan-Jones 1977-78 (supra n.7).

10 J. Beloch, *Die Bevölkerung der griechisch-römischen Welt* (Leipzig 1886); J. C. Russell, *Late ancient and medieval population* (Trans. Am. Philos. Soc. 48.3, 1958).

11 Hansen 2006 and 2008 (both supra n.1).

12 Wilson 2011 (supra n.1).

13 Hanson 2016 (supra n.1).

14 Wilson 2011 (supra n.1).

a single figure or a wide range of figures for densities to estimate their populations. There are sound reasons, however, for believing that settlements' population densities varied substantially, depending on the scale as well as the geographical region and chronological period of each. One would expect the largest settlements (Rome, Alexandria, Antioch, etc.) to have been dominated by blocks of apartments with multiple storeys, rather than single houses with one or two storeys, and to have had narrow streets and roads, as well as little open space.[15] One would also anticipate that new foundations would initially have had relatively small numbers of inhabitants and that established sites would have become increasingly crowded over time.

Most scholars have suggested that the population densities of cities would have ranged between 100 and 400 people per ha.[16] Most urban historians and geographers have suggested figures at the lower end of this range. T. Chandler and P. Bairoch both used a figure of 100 individuals per ha for Europe in the Greek and Roman periods, although they used slightly higher figures for the mediaeval and early modern, and much higher figures for more recent times.[17] According to J. C. Russell, the population density of most ancient settlements would have been "about 100-120 persons to the hectare", although he acknowledged that some settlements might have had up to 200 people per ha.[18] N. J. G. Pounds suggested that the population density of most Greek and Roman settlements was between 100 and 150 per ha, but he was mainly concerned with sites in the northwest and would almost certainly have suggested slightly higher figures for Italy and the East.[19] By contrast, most classical archaeologists and ancient historians have suggested figures towards the middle and upper end of the range suggested above. G. Storey proposed a figure of *c.*150 people per ha, based on his estimates of 166 per ha for Pompeii and 317 per ha for Ostia. This is supported by a collection of estimates for 425 cities and towns in various pre-industrial civilisations which ranged from 100 to 500 per ha but averaged 167.[20] More recently, Hansen proposed a figure of between 150 and 200 per ha, based on his estimates for 7 sites (Cassope, Haleis, Himera, Megara Hyblaea, Olynthus, Piraeus, Priene: see Table 1).[21] Wilson proposed a range of between 100 and 400 per ha based on his estimates of between 207 and 290 for Sabratha and between 286 and 357 per ha for Thamugadi.[22] Hanson used a slightly broader range of between 100 and 500 per ha based on his estimates of 160-183 per ha for Pompeii and 371 for Ostia and on his synthesis of the information provided by Hansen and Wilson.[23] Most historians and archaeologists who have worked on other civilisations have used similar figures; thus F. A. Hassan used a standard of 100 people per ha for a range of settings, although it is clear that there was a great deal of variation between different places and periods.[24]

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15 J. E. Packer, "Housing and population in Imperial Ostia and Rome," *JRS* 57 (1967) 80-95; Russell (supra n.10) 68; G. R. Storey, "The population of ancient Rome," *Antiquity* 71 [274] (1997) 966-78.

16 F. A. Hassan, *Demographic archaeology* (London 1981) 66; Wilson 2011 (supra n.1) 171.

17 P. Bairoch, *Cities and economic development: from the dawn of history to the present* (London 1988); T. Chandler, *Three thousand years of urban growth* (New York 1974).

18 Russell (supra n.10).

19 N. J. G. Pounds, "The urbanization of the classical world," *Annals Assoc. Am. Geographers* 59 (1969) 153.

20 Storey (supra n.15) 973-75.

21 Hansen 2006 (supra n.1) 22.

22 Wilson 2011 (supra n.1).

23 Hanson 2016 (supra n.1).

24 Hassan (supra n.16).

TABLE 1
THE NUMBER OF STRUCTURES, SAMPLE AREAS, AND POPULATION DENSITIES OF VARIOUS SETTLEMENTS IN THE GREEK WORLD
at or around the 4th c. B.C. (Hansen 2006 [supra n.1] Table 2.3)

Site	*Number of structures*	*Sample area (ha)*	*Population density (people per ha)*
Cassope	500	16	156.3 to 187.5
Halieis	244	4.9	249 to 298.8
Himera	8	0.25	166.7 to 200
Megara Hyblaia	55	1.75	157.1 to 188.6
Olynthus	10	0.38	131.6 to 157.9
Piraeus	8	0.25	166.7 to 200
Priene	480	15	160 to 192

A better understanding of the population densities of settlements can be used to shed light on various aspects of life, including what conditions people lived under, how close residential structures were to one another, and how large households were (and maybe whether slaves were owned by them). The population densities of settlements can also be used as an index of the number of interactions that occurred, and thus as an indication of how much innovation and invention, as well as how much crime, pollution and disease, there was likely to be in each. One would expect there to be correlation between the population densities of each settlement and both the level of wealth and overall standard of living.

An increasing amount of research on modern urbanism has used the empirical data that is available for contemporary urban centers to investigate the links between their inhabited areas and populations and various properties (e.g., their infrastructure or a number of social, political and economic measures).[25] This research demonstrates that the population of settlements and their infrastructure (e.g., public spaces, buildings, roads, electricity, gas, water, communication cables) are related in a sub-linear fashion (i.e., larger cities have fewer miles of roads *per capita* than smaller ones), exhibiting economies of scale. In addition, the population of settlements and various social, political and economic measures are related in super-linear fashion (i.e., larger cities not only have higher population densities than smaller ones, but also much higher levels of wealth, innovation and invention, as well as higher levels of poverty, crime, pollution and disease), exhibiting increasing returns to scale. This has been explained by the rôle of cities as "social reactors" which increase the number of opportunities for interactions between individuals, increasing the size of their output (whether in positive terms, such as through increased numbers of inventions and innovations, or negative ones, such as increased rates of crime, pollution and disease, etc.).

This relationship has been identified in various modern settings, most notably in the United States.[26] There is increasing evidence, however, that it can also be detected in a number of historical and archaeological contexts, such as the Basin of Mexico in the pre-Hispanic period or Europe in the mediaeval and early modern periods.[27] Although the exact nature of this relationship seems to have varied between contexts, the relationships

25 L. M. A. Bettencourt, "The origins of scaling in cities," *Science* 340 (2013) 1438-41; id. *et al.*, "Growth, innovation, scaling, and the pace of life in cities," *Proc. Nat. Acad. Sci.* 104 (2007) 7301-6; id. *et al.*, "Urban scaling and its deviations: revealing the structure of wealth, innovation, and crime across cities," *PLoS One* 5.11 (2010).

26 Ibid. (all).

27 R. Cesaretti *et al.*, "Population-area relationship for Medieval European cities," *PLoS One* 11.10 (2016); S. G. Ortman *et al.*, "The pre-history of urban scaling," *PLoS One* 9.2 (2014).

appear to be consistent enough to allow one to model them in mathematical form and to formulate a model that predicts the overall rate at which settlements will become more and more dense, taking account of the costs and benefits of interacting with other individuals in the context of a built environment.[28] According to this model, the relationship between the area and the population of a settlement can be expressed by the following equation:

$$A = aN^{\alpha}, \quad (1)$$

where A is the area, a is a constant coefficient (the baseline area per person), N is the population, and α is the exponent of the relationship.

The evidence that has been found for this relationship suggests that, although there is a small amount of variation in the baseline area per person (defined by the coefficient a), there is often a surprisingly large degree of consistency in the link between the area and the population (defined by the exponent α). The latter usually seems to have been about 5/6 or 2/3, depending on the context.[29]

This equation can then be re-arranged to solve the population in terms of area:

$$N = (1/a)^{1/\alpha} * A^{1/\alpha}$$

Since the exponents and first term are constants, however, this can be reduced to:

$$N = dA^{p}, \quad (2)$$

where $d = (1/a)^{1/\alpha}$ is a constant coefficient (the baseline population density per person) and $p = 1/a$ is the exponent of the relationship.

Finally, this equation can be expressed in terms of population density by dividing both sides by A, leading to:

$$D = dA^{p-1}, \quad (3)$$

where the population density $D = N/A$.

This raises the question of whether it is possible to detect a similar relationship in the ancient world and, if so, whether it can be used to refine the proposed ranges of population densities.

Methods

To explore this, we have attempted to compile sufficient evidence for the inhabited areas, population densities, and populations of a sample of settlements to allow us to explore the relationships between them. We have drawn on existing information about the inhabited areas of settlements, have used available material to reconstruct their population densities, and have then combined these to estimate their populations.

As Hansen and Wilson showed, it is possible to estimate the population densities of settlements if satisfactory answers can be found to the following questions:[30]

- How much of the surface area of the sites was inhabited?
- What was the average number of residential structures within each area?
- How great was the average number of individuals within each of these properties? (this in turn depends on how large the properties were, how many rooms they had, and how many storeys they had).

These questions can be answered by counting the number of properties in a given area of each site and using available evidence for the footprints of these structures, the numbers

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28 Bettencourt 2013 (supra n.25); Ortman *et al.* ibid.

29 A. T. Chamberlain, *Demography in archaeology* (Cambridge 2006) 52.

30 Hansen 2006 (supra n.1); Wilson 2011 (supra n.1).

and sizes of rooms, the average number of storeys, and the total floor area they encompassed to estimate the average number of inhabitants in each. The number of properties can be multiplied by the average number of inhabitants to estimate the total population of the properties. This figure can be divided by the total area of the properties to estimate the population density of the site. Finally, the total area of the entire site can be multiplied by the estimated population density to estimate the total population.

Most scholars have been wary about using this method for more than a few of the best-known sites, given that it requires evidence from a reasonably large sector of residential structures, as well as information about the their average sizes, number of rooms, and numbers of upper storeys — the kind of detailed evidence which is lacking for most sites due to the unsystematic way in which many were cleared in the 18th and 19th c. or due to the disconnected nature of more recent excavations (especially in the case of rescue work). Many scholars have also been cautious about using this method as there must have been much variation in the population densities from neighbourhood to neighbourhood within a settlement. Therefore it is important to think carefully about whether a sample area is representative of the site as a whole or whether it represents a district that had an atypically low or high population density. It is likely, for example, that the population densities of most sites were lower in the region of public spaces, given the amount of space that was given over to political, administrative and juridical buildings, religious structures, and commercial activities (as has long been recognised at Pompeii).[31] On the other hand, it is likely that the population densities of many sites was slightly lower towards their margins, given the possibility that there was more unconstrained development, either because of relatively open spaces in under-utilized areas leading up to the walls or because of regions where settlement had expanded along roads radiating out from the walls (illustrated by recent geophysical prospection at Ostia).[32] These issues can be circumvented by combining information from a large number of case-studies into a single data-set. This allows one to model the overall relationship between inhabited areas, population densities and site populations, producing a simple equation that can be used to estimate the populations of other sites for which we have less information. This approach means that it is possible to make use of relatively small sample areas such as a few blocks or several groups of structures since we are more interested in capturing the overall relationship across settlements rather than coming up with specific estimates for individual sites. The method should thus be thought of as a guide for individual sites; it should not be regarded as a substitute for more detailed work on them.

In using this method, we have included a range of structures, which can be divided into two main categories. The first comprises individual units, such as houses, and the second consists of multiple units, such as apartments. Since the terms normally used for these structures can be confusing (the word *insula* can refer to an individual apartment, a block of apartments or a block of streets), we have used the term 'architectural unit' to refer to

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31 D. J. Robinson, "The social texture of Pompeii," in S. E. Bon and R. Jones (edd.), *Sequence and space in Pompeii* (Oxford 1997); id., *The shape of space in Pompeii: studies in the social production of a Roman urban landscape* (Ph.D. diss., Univ. of Bradford 1999); A. Wallace-Hadrill, *Houses and society in Pompeii* (Princeton, NJ 1994).

32 M. Heinzelmann *et al.*, "Vorbericht zu einer geophysikalischen Prospektionskampagne in Ostia Antica," *RömMitt* 104 (1997) 537-48; M. Heinzelmann, "Arbeitsbericht zu einer zweiten geophysikalischen Prospektionskampagne in Ostia Antica," *RömMitt* 105 (1998) 425-29.

both entire houses and to separate apartments within each apartment block. To identify each structure, we started with entrances from streets or roads, viewing all the spaces that can be accessed from a given entrance as components of the same architectural unit.[33] This definition is not entirely unproblematic since it is possible that some entrances led to more than one architectural unit, and it is also possible that some architectural units were entered through upper storeys, but there is not enough evidence to allow one to correct for this.[34]

Another issue is whether the shops and factories that were often attached should be treated as part of the same architectural unit. There is seldom any way of making a decision, given the lack of textual or archaeological evidence for who owned these structures, whether there were doors between them, and if or how they were locked. Consequently we have had to exercise some discretion as to whether these structures were used by the same occupants or rented out to another group, even if we have usually assumed the latter for the sake of consistency. Such uncertainties about the identification of each architectural unit should not make a great deal of difference to the results, given that the numbers of shops and factories that were not occupied should be counterbalanced by the numbers of structures that contained additional residents.

A final issue is whether these structures had upper storeys and whether those consisted of additional living space for the same household or formed separate living space for a different household. Although it is relatively straightforward to deduce the presence of at least one upper storey from the presence of footings for stairs or ladders, and to estimate their rough height from thicknesses of walls or other features, it is more difficult to determine whether upper storeys covered the entire ground floor of each structure or whether they extended over the ground floors of a neighbouring structure. In most cases there is rarely enough evidence to make a decision either way. In principle, it might be possible to estimate the number of upper storeys at well-documented sites like Pompeii, Herculaneum and Ostia, and then apply these figures to other sites. The most recent research on modern cities has shown, however, that the number of upper storeys is also related to the inhabited areas, populations, and population densities of settlements, as well as to associated land values.[35] This means that it is not appropriate to apply a constant multiplier and that it would be necessary to do more detailed research to take account of these variables, but that is not feasible with the amount of evidence currently available. With these caveats in mind, we have assumed that each structure represents the residence of a single household; some occupied structures with large footprints but no upper storeys, others have smaller footprints with second storeys. The exception is when there is clear evidence of an external staircase, in which case we have treated it as an entrance to the residence of at least one additional household.

In order to determine the populations of these structures, we followed standard estimates which suggest that the size of each household ranged between 3 and 7 persons, with an average of about 5.[36] These estimates are relatively well established following a great

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33 M. Flohr, "Quantifying Pompeii: population, inequality and the urban economy," in id. and A. Wilson (edd.), *The economy of Pompeii* (Oxford 2016).

34 Ibid.

35 M. Schläpfer, J. Lee and L. M. A. Bettencourt, "Urban skylines: building heights and shapes as measures of city size," *Santa Fe Institute Working Papers* 2015.

36 Chamberlain (supra n.29) 52; cf. Hansen 2006 and 2008 (both supra n.1); Russell (supra n.10);

deal of work on the demographic structure of antiquity, such as birth and death rates, life expectancy, and the composition of households, all based upon textual sources and archaeological materials, as well as on comparisons with other civilizations.

These figures are supported by the limited evidence that can be gleaned from the census returns that have been preserved on Egptian papyri, mostly Hellenistic and Roman in date.[37] These censuses provide information for a total of 167 families, which had an average size of 4.3.[38] They were only concerned with free adult men, women and children, and did not take account of other individuals such as slaves or foreigners. As a result, the typical size of each household must have been slightly larger, in the region of 5.3.

These figures are also in keeping with what we know about the designs of some of the structures discussed below. According to Hansen, although the average sizes of houses in the Greek world ranged from 100 to 294 m^2, they had an overall average of 199 m^2 (Table 2).[39] As A. Wallace-Hadrill has shown, we also have a good sample of houses from two parts of Pompeii (*Regiones* I.vi-xii and VI.ix.-xvi) and one part of Herculaneum (*Regiones* III-VI). These houses have footprints ranging from 25 m^2 to 2,500 m^2, but which average 266, 289 and 241 m^2, respectively (average of 271 m^2). These houses probably also had an average of two storeys, and an average of 7.5 rooms each.[40] Although one cannot be certain, these structures seem appropriate to an average household of some 5 individuals, although there was clearly a great deal of variation from structure to structure.

TABLE 2
AVERAGE AREAS OF STRUCTURES IN VARIOUS SETTLEMENTS IN THE GREEK WORLD at or around the 4th c. B.C. (Hansen 2006 [supra n.1] Table 2.1)

Site	*Average area (m^2)*	*Site*	*Average area (m^2)*
Abdera	200	Horraon	270
Athens	100-200	Metapontum	215
Camarina	204	Miletus	260
Casmenae	156	Olbia	80-120
Cassope	225	Olynthus	294
Cercinitis	85-130	Piraeus	240
Chersonesus	156-159	Priene	207
Colophon	100-200	Selinous	220
Croton	289	Sybaris	136
Halieis	175	Tarracina	238
Heracleia	200	Thasos	125
Himera	256	**Average**	199

To define urbanism, we have used a similar definition to the ones used by Hansen in his study of the Greek world in the Classical period and Hanson in his study of the Roman world in the Imperial era.[41] Although it is notoriously difficult to define urbanism, we can come up with a working definition by concentrating on sites that are more likely to have

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Storey (supra n.15); Wilson 2011 (supra n.1).

37 Kennedy (supra n.1) 111.

38 R. S. Bagnall and B. W. Frier, *The demography of Roman Egypt* (Cambridge 1994); Hansen 2006 (supra n.1) 58; id. 2008 (supra n.1) 278.

39 Hansen 2006 (supra n.1) Table 2.1.

40 Wallace-Hadrill (supra n.31) 64-67, 76 and 100.

41 Hansen 2006 and 2008 (supra n.1); Hanson 2016 (supra n.1).

engaged in secondary and tertiary, rather than primary, activities, which can be gauged by whether they had a certain population (such as 1000, 5000, or more individuals) or offered certain functions (such as historical, social, cultural, religious, political, administrative, juridical, and economic rôles). Although we lack direct evidence for these features, we can approximate them by looking at the size of inhabited areas, monumentality, and civic status. This provides a number of criteria, which include not only whether sites conform to thresholds of 10 or 50 ha (which are used to estimate the numbers of inhabitants in them), but also whether they had monuments, such as public spaces, associated public buildings, urban grids, leisure and entertainment structures, and religious, sanitation and defensive structures, and whether they had civic statuses (e.g., as provincial, *conventus*, *metropolis* or nome capitals, *coloniae*, *municipia*, *civitates*, *poleis*, or various other rights and privileges). These features do not necessarily coincide, with the result that there are a small number of sites that do not meet the criteria for size but nonetheless have significant monumentality or civic status. However, since most scholars have used thresholds (e.g., 1000 and 5000 individuals) to study the urbanism of other times and places, it is necessary to use the same thresholds to estimate the overall urban population, the urbanization rate and the total population, and then compare them to other civilizations (see further discussion below).

Accordingly, we have restricted ourselves to sites included in Hansen's study of the Greek world at or around the 4th c. B.C. and Hanson's study of the Roman world between 100 B.C. and A.D. 300. The sites included in these two catalogues often overlap; they include a wide range of sites, including capitals, *coloniae* and *municipia*, and the various kinds of *civitates* and *poleis* that were accorded various rights and privileges. As these sites also encompass a wide area over a long period, they are not strictly co-terminous in geographical or chronological terms.

The data-set

In the following paragraphs, we discuss the details involved in compiling a data-set for the population densities of a sample of settlements throughout the Greek and Roman world from the 4th c. B.C. to the 6th c. A.D. To create this sample, we worked with a combination of maps, plans and satellite images, counted the numbers of residential structures, and calculated the size of the area in which they occurred. In most cases, we included spaces between and around the edges of residential structures in our estimates of area, but we have excluded spaces that were devoted to non-residential uses unless we were working with large exposed areas (as at Pompeii, Herculaneum and Ostia). As the evidence for each of these sites is extremely varied, our estimates for some are better than others. Yet taking out these kinds of sites makes little difference to the overall results.

Rome and other large cities

We begin with Rome and the other most important settlements. It is virtually impossible to estimate the number of residential structures in these with any certainty owing to the lack of direct textual and archaeological evidence, compounded by the fact that most have been occupied continuously since antiquity. Nevertheless, it is worth reviewing the evidence that does exist since we might expect these settlements to have had higher population densities than others, enabling us to set an upper limit for population densities of settlements in the ancient world.

In discussing the size and population of Rome, it has become traditional to refer to the "Regionary Catalogues", the *Notitia* and *Curiosum*, both dating to the early 4th c. A.D. These

offer information about the total numbers of various types of buildings in the city: e.g., that there were a total of 1790 *domus* and 46,602 *insulae*, along with hundreds of baths, brothels, bakeries and warehouses.[42] There are substantial difficulties associated with these figures, however, since these sources were not intended to be a reliable record of the numbers of buildings in the city and clearly exercise a degree of creative license. Moreover, the figures are internally inconsistent, as illustrated by the mismatch between the numbers given in the summaries and the actual totals. It is also virtually impossible to extrapolate from these figures to an estimate of the total population since there is no evidence for how many individuals should be allocated to each structure. This is particularly problematic for the *insulae*, where there are no grounds for deciding whether the term refers to entire blocks or to individual apartments inside them. As a result, attempts to use these figures have generally led to estimates that are either much too low or much too high to be realistic.

Another source of information is the *Forma Urbis Marmorea*, a diagram of the capital set up in the 3rd c. A.D., which marks both the outlines and internal divisions of public and private buildings.[43] In theory, it might be possible to estimate the numbers and sizes of the structures shown on it, especially in the light of work recently done to re-assemble the 1186 surviving fragments on one chart.[44] In reality, however, there are too many issues with the evidence for such an attempt to be of much use, given concerns over the accuracy and precision of the surveys it was based on, the fact that it prioritizes public spaces over private areas and represents different areas at different scales, and inasmuch as it does not represent upper storeys. The diagram is still useful, however, since it suggests that the city was dominated by small, irregularly-shaped, densely-packed structures, mainly occupied by shops or factories on the ground floor and apartments on the upper storeys.[45]

We also have evidence for several individual buildings or groups of buildings, such as two *domus*-type houses on the slope of the Palatine and various *insula*-type apartments uncovered at the foot of the Capitol, on the slopes of the Quirinal and Caelian, adjacent to the *Via Flaminia*, and built into the façades of churches such as SS. Giovanni e Paolo on the Clivus Scauri and S. Anastasia in the Velabrum.[46] This evidence lends support to the idea that the population density of the capital was quite high, but it is too fragmentary to allow one to estimate the population density of specific areas with any precision, since often we do not have enough evidence to reconstruct an entire structure, let alone a number of them.[47]

The evidence for other large cities is also extremely limited. There is some textual evidence for Alexandria in the form of the *Syriac Notitia* dating to the 4th c. A.D., which details 47,790 houses and 8,102 courts.[48] As in the case of the *Regionary Catalogues*, it is virtually impossible to make sense of these figures, especially since there are issues with deciding

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42 A. Wallace-Hadrill, *Rome's cultural revolution* (Cambridge 2008) Table 6.1.

43 E. Rodriguez-Almeida, *Forma Urbis Marmorea: aggiornamento 1980* (Rome 1981); Wallace-Hadrill ibid.

44 http://formaurbis.stanford.edu/index.html (viewed June 9, 2016).

45 Packer (supra n.15) 81.

46 F. Coarelli, *Rome and environs: an archaeological guide* (London 2007); Packer ibid.; J. R. Paterson, "Living and dying in the city of Rome: houses and tombs," in J. C. Coulston and H. Dodge (edd.), *Ancient Rome: the archaeology of the eternal city* (Oxford 2000) 260 and 275.

47 A possible exception are the structures from the Palatine, but these are far from representative since the area only includes a couple of *domus*-type houses and no *insula*-type apartments.

48 Russell (supra n.10).

how many individuals might have lived in these structures. Yet some archaeological evidence allows one to estimate the number of buildings in the area known as Kom el-Dikka, which includes about 23 houses within 3 blocks encompassing 0.17 ha.[49]

There is no evidence of any kind for Antioch, since not one of the houses discovered in the center or at Daphne is known in its entirety.[50] Similarly, there is little evidence for Carthage, other than some fragmentary information from isolated areas. At Ephesus, there is evidence for *c.*30 structures in the two blocks on the S slope of the Bülbüldağ ("Hanghaus 1 and 2"), which cover an area of 0.7 ha.[51]

Other settlements

Next we summarize the available evidence for other settlements, beginning with information previously compiled by Hansen, Wilson and Hanson, followed by a summary of our new work on settlements.

As Wilson noted, we possess two examples of ancient censuses that include a count of houses, both relating to Egypt in the Roman period, although one should be cautious given the various issues with ancient figures.[52] The first document, pertaining to Hermopolis Magna, records a total of 4,200 houses and dates to the mid-3rd c. Since these houses are concentrated in 2 out of a total of 4 quarters, it would suggest a total of *c.*7,000 houses on the assumption that there were fewer houses in the other quarters. The site covers between 150 and 160 ha. The second document, relating to Thmuis, records 3,560 houses and dates to the mid-2nd c. The site covers between 80 and 90 ha. There are also house counts for some additional sites, such as Apollonopolis, where there is evidence for 1,273 houses, but it is not possible to measure the inhabited areas of these sites very accurately.

As Hansen has shown, it is possible to estimate the population densities of 7 sites in the Greek world at or around the 4th c. B.C. (Table 1).[53] A rough estimate for Metapontum can be added to these: it has been estimated that there were *c.*3,000 structures in the urban grid, which covered *c.*70 ha.[54] There is also exceptional evidence from Delos, a consequence of its sharp decline during the 1st c. B.C. According to A. Papageorgiou-Venetas, there was a total of 50 structures in the area around the theatre which covers *c.*1.6 ha.[55] We can also reconstruct the original numbers of structures in a couple of blocks at Paestum, although the nature of its domestic architecture in later periods is a little more complex.

According to Wilson, it is possible to estimate the populations of two sites in N Africa in the Roman period.[56] The first, Sabratha, was extensively cleared at the beginning of the last century, revealing an urban grid north of the theatre which dates to the late 2nd c. A.D.[57] This consists of 29 blocks, each divided into 4 architectural units (each covered *c.*100m^2, arranged around a central courtyard with 5 to 7 rooms, and spanned two storeys),

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49 J. MacKenzie, *The architecture of Alexandria and Egypt, 300 B.C.–A.D. 700* (New Haven, CT 2007).
50 R. Stillwell, "Houses of Antioch," *DOP* 15 (1961) 45 and 47-57.
51 E. Akurgal, *Ancient civilizations and ruins of Turkey* (Istanbul 2002).
52 A. K. Bowman, "Ptolemaic and Roman Egypt: population and settlement," in id. and Wilson 2011 (supra n.1) 343.
53 Hansen 2006 and 2008 (supra n.1).
54 J. C. Carter, *Discovering the Greek countryside at Metaponto* (Ann Arbor, MI 2006).
55 A. Papageorgiou-Venetas, *Délos: recherches urbaines sur une ville antique* (Munich 1981).
56 Wilson 2011 (supra n.1)
57 Ibid. 172.

indicating that there was a total of 116 structures in an area of 2.54 ha. The second, Thamugadi, was also extensively cleared in the first half of the 20th c., revealing the urban grid of the original *colonia*, which dates to A.D. 100.[58] It comprised 132 blocks, of which 23 were non-residential. The majority were divided into 8 architectural units (each covering *c.*50 m^2 and spanning two storeys), yielding a total of 711 structures in an area of *c.*9.96 ha. In addition, there is some evidence for Meninx, since it is possible to reconstruct 6 structures in one block of the site covering *c.*0.25 ha.[59]

Aside from these, the most secure evidence comes from Pompeii, Herculaneum and Ostia. The most recent assessment of **Pompeii** indicates that there were a total of 1,151 structures in the excavated area which covers *c.*44.32 ha.[60] This includes 498 structures that can be classified as houses, 468 as *tabernae* and 133 as apartments, while another 52 resist categorization. We are badly informed about the upper storeys, although the ones that are known have been included. The structures have an average footprint of 193 m^2 but usually more than one floor, yielding an average of 8.8 rooms. This inevitably means that our figure for the number of structures at Pompeii will be a slight overestimate, since not all of these shops and factories would have been inhabited. As we will see below, however, this does not seem to have too great an effect on our overall results, since the figure for this site is consistent with the overall relationship between inhabited areas and population density at the other ancient settlements. At **Herculaneum**, there were at least 80 structures in the exposed sector, which covers *c.*3.73 ha.[61] This includes 12 structures that can be categorized as *atrium* houses, 8 houses with peristyles or enclosed porticoes, 20 *tabernae*, 12 small habitations or large commercial properties, 19 apartments, and 9 structures with irregular forms. Here we have excellent evidence for the number of upper storeys, leading to confidence about the distribution of architectural units over different levels. These structures have an average footprint of 158 m^2 but an average of 1.4 floors (including mezzanines), resulting in an average overall area of 244 m^2 (there is no evidence for the average numbers of rooms). At **Ostia,** in the excavated part of the site (*c.*35 ha), there is evidence for a total of 3,153 structures, including 22 private mansions, 126 shop and factory buildings (types I and III) that were divided into 2,693 architectural units, and 58 buildings with ground floor flats (type II) that were divided into 438 architectural units.[62] There is no information about the sizes of the architectural units, but there is evidence that suggests that they had an average of 3.6 floors, and that shop and factory buildings had an average of 1.7 rooms. (Additional areas have been brought to light by geophysical prospection, but there is no way to integrate these findings because doorways and passageways are not visible in the images, which prevents us from defining architectural units.[63])

It is possible to estimate the number of structures at various other sites at different dates so long as there is enough evidence for residential areas. This is the case with Volubilis, where there is evidence for 182 structures in the NW quarter in an area covering *c.*4.32 ha.[64]

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58 Ibid. 175.

59 E. Fentress, "Peopling the countryside: Roman demography in the Albegna Valley and Jerba," in Bowman and Wilson 2009 (supra n.1) 136.

60 Flohr (supra n.33); Robinson 1997 and 1999 (both supra n.31); Wallace-Hadrill (supra n.31).

61 J. N. Andrews, *The use and development of upper floors in houses at Herculaneum* (Ph.D. diss., Univ. of Reading 2006) Tables 4.2-4.6 and 4.9; Wallace-Hadrill ibid.

62 Packer (supra n.15); id., *The insulae of Imperial Ostia* (MAAR 71; 1971) Charts I-II.

63 Heinzelmann *et al.* 1997 and Heinzelmann 1998 (both supra n.32).

64 R. Etienne, *Le quartier nord-est de Volubilis* (Paris 1960).

It is also true of Cuicul, where there are 74 structures in one area ("quartier occidental") east of the forum that covers *c.*6.35 ha, and of Conimbriga, where there are 14 structures in one area east of the forum that covers *c.*1.06 ha.[65] This evidence can be supplemented with information about a few more sites, although the available material is confined to relatively small parts of each site. The most important is Athens, where there is evidence for 6 structures in one block on the N slope of the Areopagus that covers *c.*0.07 ha;[66] similar results can be derived from other parts of the site, such as the area of the Agora. At Pergamum, there were *c.*13 structures in one block on the S slope of the hill below the Upper Agora that covers 0.22 ha.[67] There is a selection of other sites where there is evidence for at least one block, although the quality and quantity of the evidence varies: they include Neapolis; Morgantina and Tyndaris; Palmyra; Side; Banasa; Bulla Regia, Gigthis and Utica; Augusta Emerita, Celsa, Emporiae and Italica; Alesia, Glanum, Lugdunum and Vasio. The evidence for some of these (e.g., Bulla Regia, Augusta Emerita) is more approximate as it was more difficult to reconstruct the exact numbers and sizes of structures. One can obtain some evidence for a number of new foundations, since it is relatively easy to reconstruct the number of houses originally intended for each block. At Cosa we can reconstruct a total of *c.*258 structures (this figure is slightly speculative — different figures have been given), in the urban grid of the original *colonia*, which covered *c.*10 ha.[68] These structures have an average footprint of 317 m^2, although little is known about the numbers of upper storeys or average numbers of rooms. We can also use information provided by M. Conventi to reconstruct the numbers of structures in whole sites or in sections of sites in Roman Italy, such as Augusta Praetoria, Libarna, Luna, Venusia and Verona, as well as Fregellae which did not survive into the Imperial era.[69] In the Roman northwest, as structures were built in a mixture of masonry and timber elements, they were often not noted by early excavators and may not be apparent in aerial photography or from geophysical prospection. Yet it is possible to derive some evidence for the number of structures at some of the best known sites, such as London, where there have been rescue excavations at Newgate Street, or Verulamium and Calleva, where there has been extensive research on *Insulae* XXVIII and XIV and on *Insula* IX, respectively.[70]

Results

When all this information is compiled, it provides evidence for 52 sites from a sample drawn from across the settlement hierarchy (sizes ranging from 12 to 972 ha), as well as across a wide area and a long period (the entire Mediterranean and its periphery, from the 4th c. B.C. to the 6th c. A.D.; see figs. 1-2). The sample has a wide range of granularity since it includes entire sites as well as specific areas of sites, individual blocks, and separate groups of buildings. The sample also includes differing amounts of residential and non-residential areas, depending on the exact nature of the evidence used for each. This list should not be regarded as exhaustive; it might be possible to obtain information for a few

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65 J. Alarcão and R. Etienne, *Fouilles de Conimbriga* (Paris 1977); Y. Allais, "Le quartier occidental de Djemila (Cuicul)," *AntAfr* 5 (1971) 95-120.

66 L. C. Nevett, *House and society in the ancient Greek world* (Cambridge 1999).

67 W. Radt, *Pergamon: Geschichte und Bauten einer antiken Metropole* (Darmstadt 1999).

68 E. Fentress, *Cosa* V: *an intermittent town* (MAAR Suppl. 2; 2003) 23-26; ead. (supra n.59).

69 M. Conventi, *Città romane di fondazione* (Rome 2004).

70 S. S. Frere, *Verulamium excavations*, vols. I-III (Oxford 1972-84); M. Fulford and A. Clarke, *Silchester: city in transition. The mid-Roman occupation of Insula IX* (Britannia Monog. 25, 2011); M. Millett, *The Romanization of Britain: an essay in archaeological interpretation* (Cambridge 1990).

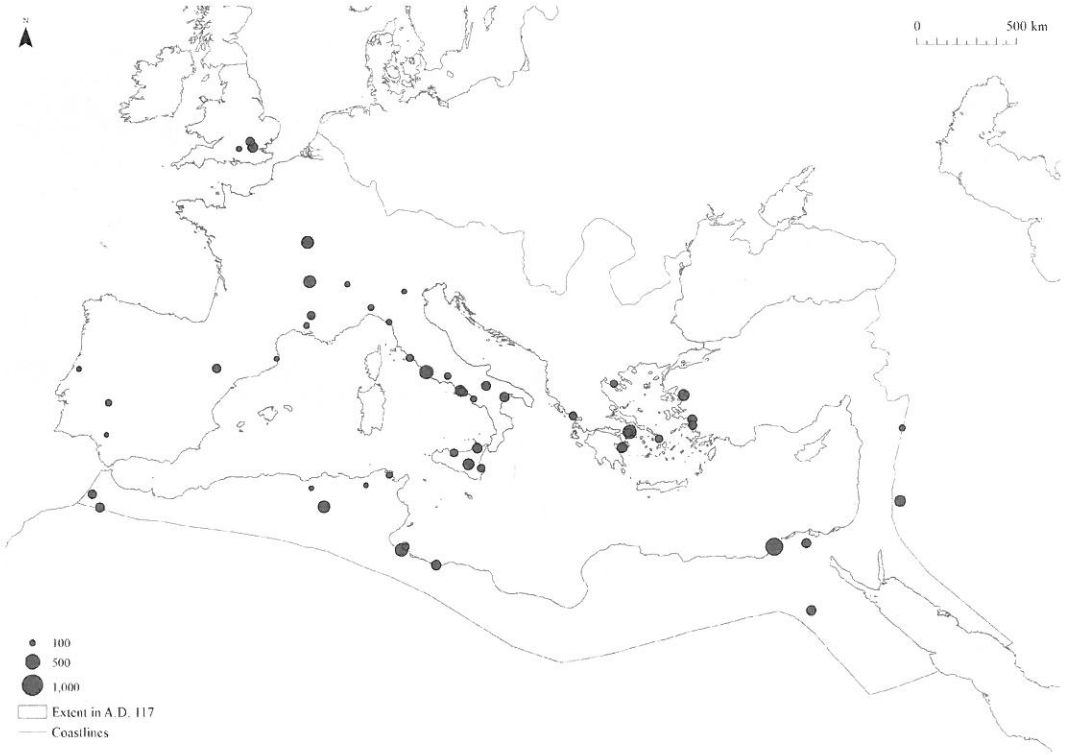

Fig. 1. Distribution and estimated population densities of various settlements in the Greek and Roman worlds.

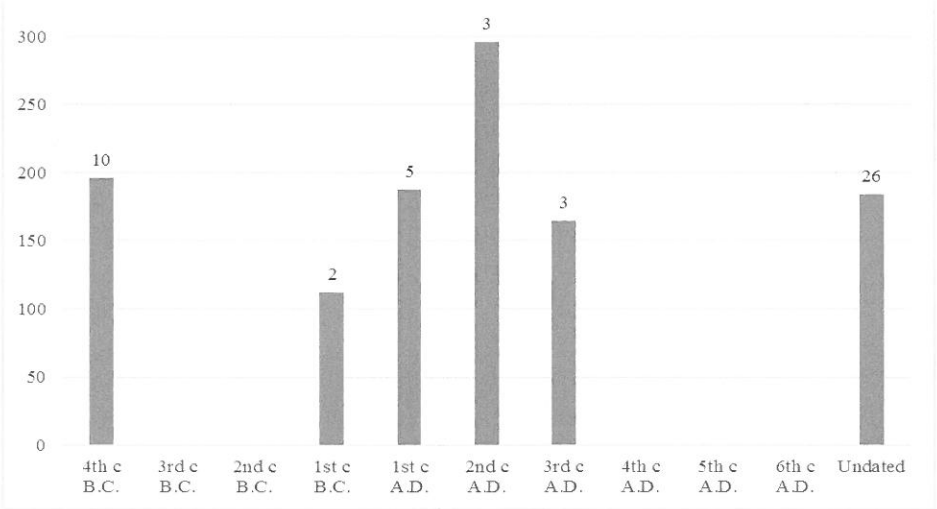

Fig. 2. Average estimated population densities of selected settlements in each century (those with only one estimated density have been excluded); sample sizes are given above each.

more sites after more excavation, survey or archival research.[71] In addition, the method

71 These include: Agrigentum, Alba Fucens, Alba Helviorum, Albintimilium, Altinum, Ammaedara, Apamea, Apollonia, Aquileia, Aquincum, Ariassos, Assus, Augusta Bagiennorum, Augustobona, Baelo, Baetulo, Berytus, Blaunus, Boutae, Bracara, Brigantium, Buthrotum, Caerwent, Carsulae, Carthago, Clunia, Concordia, Corinium, Corinthia, Corstopitum, Cyaneae, Cyrene, Dium, Eleusis, Eretria, Falerii Novi, Flavia Solva, Forum Claudii, Grumentum, Hadrianopolis, Heraclea (Asia), Herdoniae, Hippo Regius, Histria, Industria, Isca, Lauriacum,

TABLE 3
THE NUMBER OF PROPERTIES, SAMPLE AREAS, AND ESTIMATED POPULATION DENSITIES OF VARIOUS SETTLEMENTS IN THE GREEK AND ROMAN WORLD

Site	*No. of structures*	*Sample area (ha)*	*Population density (people per ha)*
Alesia	10	0.14	357
Alexandria	23	0.17	676
Athens	6	0.07	429
Augusta Emerita	36	1.5	120
Augusta Praetoria	4	0.24	83
Banasa	23	0.63	183
Bulla Regia	11	0.94	59
Calleva	4	0.25	80
Cassope	500	16	156
Celsa	11	0.3	183
Conimbriga	14	1.06	66
Cosa	258	10	129
Cuicul	74	6.35	58
Delos	50	1.6	156
Emporiae	5	0.4	63
Ephesus	30	0.7	214
Fregellae	7	0.28	125
Gigthis	9	0.11	409
Glanum	5	0.24	104
Halieis	244	4.9	249
Herculaneum	80	3.73	107
Hermopolis Magna	7,000	155	226
Himera	8	0.24	167
Italica	24	1.85	65
Libarna	12	0.6	100
Londinium	2	0.04	250
Lugdunum	20	0.28	357
Luna	4	0.25	80
Megara Hyblaea	55	1.75	157
Meninx	6	0.25	120
Metapontum	3,000	70	214
Morgantina	8	0.14	286
Neapolis	55	1	275
Olynthus	10	0.38	132
Ostia	3,153	35	450
Paestum	20	0.96	104
Palmyra	2	0.11	91
Pergamum	13	0.22	295
Piraeus	8	0.24	167
Pompeii	1,151	44.32	130
Priene	480	15	160
Sabratha	116	2.54	228
Side	6	0.1	300
Thamugadi	711	9.96	357

TABLE 4
TOTAL AREAS, POPULATION DENSITIES, AND ESTIMATED POPULATIONS OF VARIOUS SETTLEMENTS IN THE GREEK AND ROMAN WORLD

Site	*Total area (ha)*	*Population density (people per ha)*	*Estimated population*
Alesia	97	357	34,643
Alexandria	987	676	667,676
Athens	225	429	96,429
Augusta Emerita	81	120	9,720
Augusta Praetoria	41	83	3,417
Banasa	15	183	2,738
Bulla Regia	31	59	1,814
Calleva	45	80	3,600
Cassope	30	156	4,688
Celsa	18	183	3,300
Conimbriga	23	66	1,519
Cosa	14	129	1,806
Cuicul	12	58	699
Delos	95	156	14,844
Emporiae	21	63	1,313
Ephesus	263	214	56,357
Fregellae	80	125	10,000
Gigthis	50	409	20,455
Glanum	32	104	3,333
Halieis	18	249	4,482
Herculaneum	20	107	2,145
Hermopolis Magna	155	226	35,000
Himera	82	167	13,667
Italica	49	65	3,178
Libarna	20	100	2,000
Londinium	160	250	40,000
Lugdunum	170	357	60,714
Luna	23	80	1,840
Megara Hyblaea	140	157	22,000
Meninx	43	120	5,160
Metapontum	150	214	32,143
Morgantina	25	286	7,143
Neapolis	82	275	22,550
Olynthus	35	132	4,605
Ostia	154	450	69,366
Paestum	126	104	13,125
Palmyra	120	91	10,909
Pergamum	220	295	65,000
Piraeus	141	167	23,500
Pompeii	60	130	7,791
Priene	37	160	5,920
Sabratha	35	228	7,992
Side	38	300	11,400
Thamugadi	50	357	17,846

TABLE 3 *(continued)*

Thmuis	3,560	85	209
Tyndaris	9	0.19	237
Utica	6	0.32	94
Vasio	25	0.83	151
Venusia	3	0.07	214
Verona	8	0.59	68
Verulamium	11	0.3	183
Volubilis	182	4.32	211

TABLE 4 *(continued)*

Thmuis	85	209	17,800
Tyndaris	30	237	7,105
Utica	85	94	7,969
Vasio	36	151	5,422
Venusia	44	214	9,429
Verona	52	68	3,525
Verulamium	90	183	16,500
Volubilis	43	211	9,058

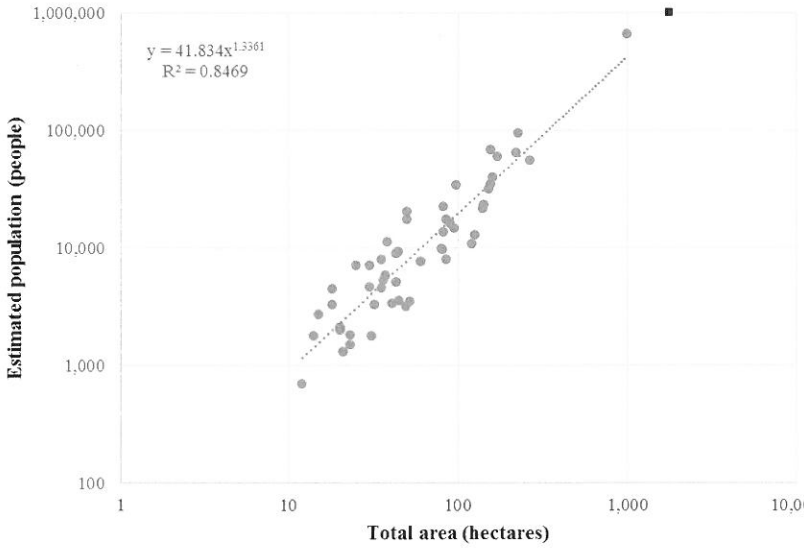

Fig. 3. Log-log graph showing relationship between the settled area (in ha) and estimated populations of various settlements; the black square represents commonly-cited estimates for the settled area and population of Rome.

could be extended to smaller settlements, villages and hamlets (that would entail drawing on the rich evidence for Egypt and Syria, such as Karanis and perhaps Philadelphia and Theadelphia).[72]

Once this information has been compiled, we can multiply the numbers of structures by the figure for the average number of inhabitants (discussed above) to estimate their populations. We can divide these values by the size of the sample area to estimate the population densities. This provides us with the figures given in Tables 3 and 4, which we have tested statistically in Table 5. This information has then been plotted on a log-log graph in fig. 3.

When compared with what we would anticipate on the basis of other lines of evidence, some of the estimates for sites in Tables 3-4 are more reliable than others. The errors seem to be directly related to the limitations of the available data, such as the representativeness of the sample used, the exactness with which the number of residential structures and size of the sample area could be determined, and the extent of the sample area that was taken

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Lepcis Magna, Lixus, Lucentum, Lucus Feroniae, Mirobriga, Munigua, Nesactum, Nora, Oenoanda, Phellus, Philadelphia, Philippi, Pollentia, Privernum, Ptolemais, Pupput, Rapidum, Saepinum, Salona, Sentinum, Sepphoris, Serdica, Seuthopolis, Soluntum, Stobi, Sufetula, Tarragona, Teos, Thamuda, Thamusida, Thasos, Theadelphia, Thoricus, Thuburbo Maius, Thugga, Tiddis, Tipasa, Tocra, Troesmis, Virunum and Xanthus.

72 Bowman (supra n.52) 335.

up by open spaces, streets, and other structures. It is also clear that the errors can be found throughout the sample of sites and are not related to the sizes of each settlement or their location or date. This suggests that the errors are unlikely to distort the results in favour of one type of site or one region and/or period.

It is possible to examine the fit of the data to equations 3, 2, and 1, respectively (Table 5). The estimated exponents, coefficients, and confidence intervals for each fit are derived from ordinary least-squares regression of the log-transformed data.[73] The sample is large enough to invoke the central limit theorem, which states that the values of a sufficiently large number of observations of an independent random variable will be distributed according to a normal distribution. Thus, errors in estimating regression parameters will also be normally-distributed, which allows one to calculate meaningful confidence intervals around these estimates.

TABLE 5
QUANTITATIVE RELATIONSHIPS BETWEEN THE INHABITED AREAS, POPULATION DENSITIES, AND TOTAL POPULATIONS OF VARIOUS SETTLEMENTS IN THE GREEK AND ROMAN WORLD

	Sample data (N=52)	*Sample data + Rome*[1] *(N=53)*
A. Area *versus* population density		
Exponent	.336	.341
(95% C.I.)	(.178 - .493)	(.203 - .479)
Coefficient (people per ha)	41.89	41.08
(95% C.I.)	(21.82 - 80.43)	(22.94 - 73.56)
R^2	.260	.32
P-value	.0001	<.0001
B. Area *versus* estimated population		
Exponent	1.34	1.34
(95% C.I.)	(1.18 - 1.49)	(1.20 - 1.48)
Coefficient (people per ha)	41.84	41.03
(95% C.I.)	(21.78 - 80.37)	(22.90 - 73.52)
R^2	.847	.877
P-value	<.0001	<.0001
C. Estimated population *versus* area		
Exponent	.634	.654
(95% C.I.)	(.559 - .709)	(.587 - .721)
Coefficient (ha per people)	.174	.146
(95% C.I.)	(.087 - .348)	(.078 - .274)
R^2	.847	.877
P-value	<.0001	<.0001

1 Includes text-based estimates for Rome at its peak in the Imperial period (population 1,000,000, inhabited area 1783 ha, population density 561 persons per ha).

As demonstrated by Table 5, there are surprisingly strong relationships between the inhabited areas, population densities, and populations of these sites. This is borne out by the fact that the 95% confidence intervals around the exponents and coefficients are comparatively narrow and the fact that the values for the R^2 and the P-value are relatively high and low, respectively. As seen below, it is also striking that expanding the sample to

73 This is because y = axb and log y = log a + b*log x are equivalent. See Bettencourt 2013 (supra n.25) and Ortman *et al.* (supra n.27) for details concerning this method.

include Rome (taking the widely accepted estimate of 1 million inhabitants, and dividing it by the inhabited area of the site to make a suggestion about its population density) has a negligible effect on the results, indicating that the trend is remarkably robust and likely to continue after information about other settlements has been added. This suggests that it is possible to use the information given above to reconstruct the overall relationship between inhabited areas, population densities, and populations of these sites, despite the fact that there are some errors in the evidence available for individual sites.

The exponent of the relationships between inhabited area and population density is *c.*⅓, between inhabited area and population *c.*4/3, and between population and inhabited area *c.*⅔. All of these values are consistent with the expectations of the models discussed above. The results indicate that the population densities of ancient settlements increased as they grew, and at rates that are nearly identical to those that have been obtained for other civilizations (e.g., Europe in the mediaeval period; Central and North America before modern times).[74]

Discussion

The information given above demonstrates that there are strong relationships between the inhabited areas, population densities, and populations of these settlements, which is consistent with the theories discussed above. This suggests that it might be possible to use the equation shown on the graph above (fig. 3) to estimate the populations of other sites in the ancient world, since it allows us to multiply existing measurements of the inhabited areas of each site by our forecasts for their population densities in order to estimate their populations. To examine whether this is true, we can make use of existing information about the inhabited areas of some of the most important settlements, which are shown in Table 6.

TABLE 6
TOTAL AREAS, POPULATION DENSITIES, AND NEW ESTIMATED POPULATIONS OF SELECTED SETTLEMENTS, COMPARED WITH THEIR TRADITIONAL ESTIMATED POPULATIONS

Site	*Total area (ha)*	*Population density (people per ha)*	*New estimated population*	*Traditional estimated population*
Rome	1,783	518	923,406	1,000,000
Alexandria	972	422	410,535	500,000
Antioch	399	313	124,936	150,000
Carthage	343	298	102,079	100,000
Ephesus	263	272	71,587	100,000
Ostia	154	227	35,017	25,000-30,000
Pompeii	60	166	9,938	10,000
Herculaneum	20	115	2,290	5,000

As Hanson has shown, the area of Rome was *c.*1,783 ha, which suggests a population density of 518 persons per ha and a total population of *c.*923,000. The latter is almost identical to the figure of about 1 million that is typically cited by scholars (this is especially notable given that Rome falls outside the range of sites in the sample).[75] The area of Alex-

74 Bettencourt 2013 (supra n.25); Cesaretti *et al.* (supra n.27); S. G. Ortman and G. D. Coffey, "Universal scaling: evidence from village-level societies," *Santa Fe Institute Working Papers* 2015; Ortman *et al.* (supra n.27).

75 Beloch (supra n.10); K. Hopkins, "Economic growth and towns in classical antiquity," in

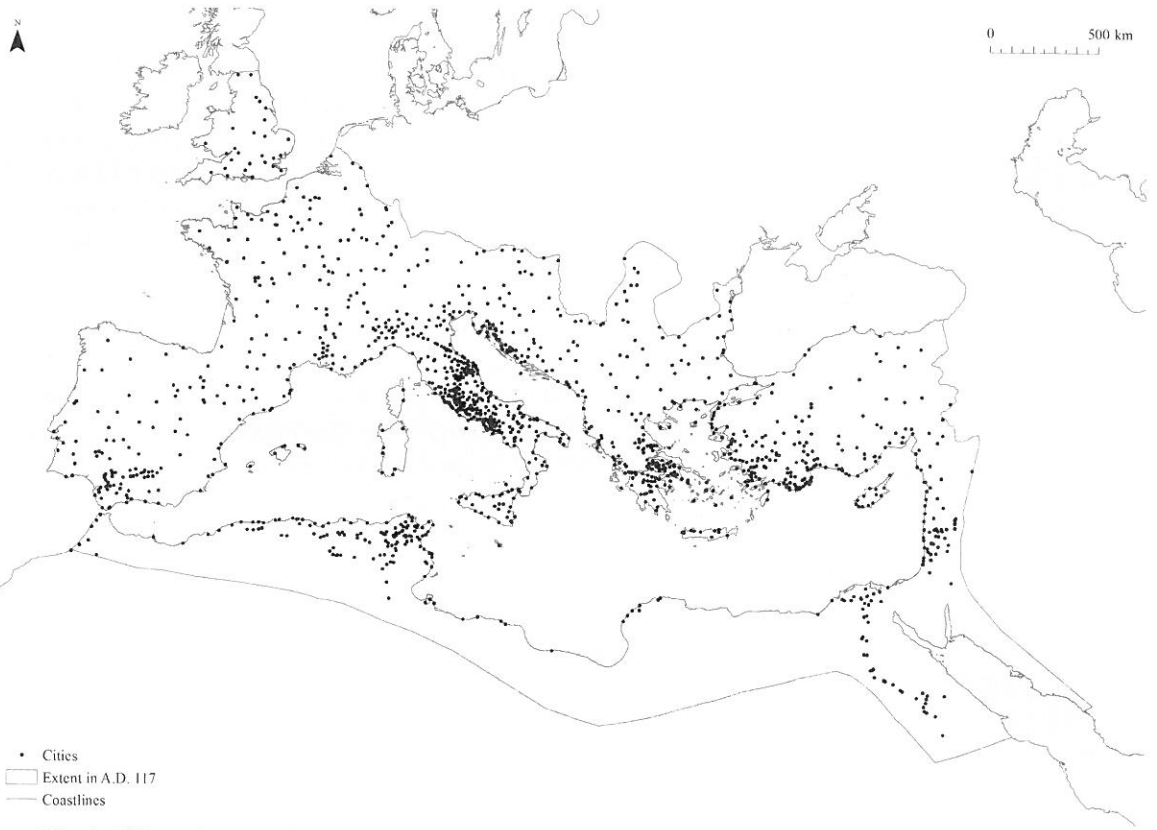

Fig. 4. Cities and towns of the Roman world in the Imperial age (after Hanson 2016 [supra n.1]).

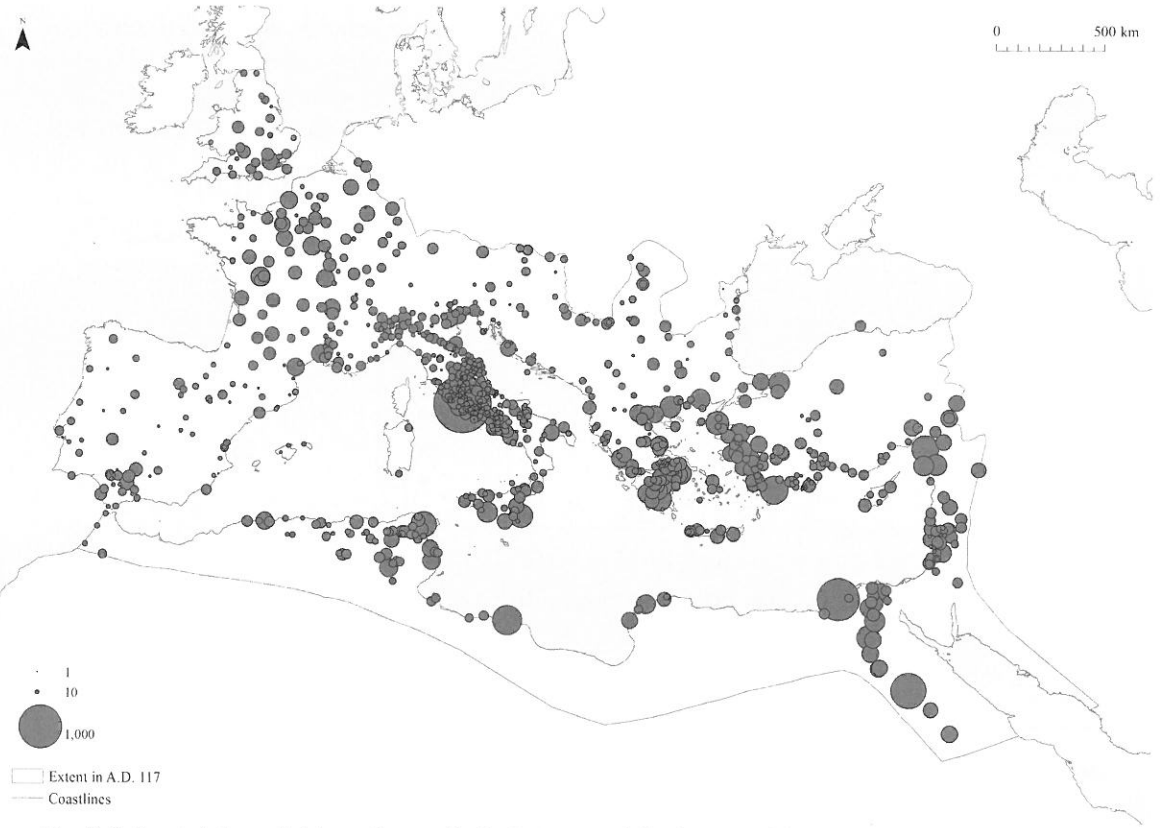

Fig. 5. Estimated sizes of cities and towns in the Roman world in the Imperial age (after Hanson 2016 [supra n.1]).

andria was *c.*972 ha, which suggests a population of *c.*411,000 (at 422 persons per ha). This is broadly in line with the figure of about 500,000 that has been cited by scholars.[76] The area of Antioch was *c.*399 ha, suggesting a population of *c.*125,000 (at 313 persons per ha); the area of Carthage was *c.*343 ha, suggesting *c.*102,000 (at 298 persons per ha); and the area of Ephesus was *c.*263 ha, suggesting *c.*72,000 (at 272 persons per ha) — estimates which compare favourably with figures of *c.*150,000 for Antioch and *c.*100,000 for Carthage and Ephesus that have been put forward in previous studies.[77]

The equation also seems to work well for other well-known sites. The area of Pompeii was at least 60 ha, suggesting a population of *c.*10,000 (at 166 persons per ha). This is identical to the figure of about 10,000 proposed by Wallace-Hadrill and others.[78] The area of Ostia was *c.*154 ha, suggesting a population of *c.*35,000 (at 227 persons per ha). This figure is somewhat lower than the 50,000-60,000 suggested by R. Meiggs, but only a little higher than the 25,000-30,000 suggested by more recent scholars such as J. E. Packer and G. R. Storey.[79] In other cases, the equation can be used to probe assertions that have been made about specific sites. For example, L. de Ligt has suggested that Herculaneum encompassed *c.*20 ha, on the basis of comparing the small area that has been excavated with what is known about other sites in the region of Vesuvius.[80] The equation given in the present study suggests a population of *c.*2,000 (at 115 persons per ha), whereas most other scholars have suggested a population of about 4,000-5,000.[81] This discrepancy suggests either that the site was larger than suggested, that previous estimates of its population have been too generous, or that the site diverges from the overall trend for other reasons which are in need of research.

These results suggest that the equation can be used more widely to estimate the populations of other settlements in the ancient world. If this is true, it should allow us to estimate the size of the overall urban population, the urbanization rate, and the total population. To do this, most scholars have used the thresholds of 1,000 or 5,000 individuals to define cities in the ancient world, although higher figures have been used for later periods (e.g., 5,000 and 10,000 for the mediaeval and early modern periods, and between 10,000 and 100,000 for the industrial and post-industrial periods).[82] We have followed the convention of using the thresholds of 1,000 and 5,000 individuals for the ancient world, and used the latter for the sake of comparison with more recent times (which is the same as the one used by both Chandler and Bairoch for the mediaeval and early modern worlds).

P. Abrams and E. A. Wrigley, *Towns in societies: essays in economic history and historical sociology* (Cambridge 1978) 96-98, Appendix; N. Morley, *Metropolis and hinterland: the city of Rome and the Italian economy, 200 B.C.–A.D. 200* (Cambridge 1996) 2 and 33-39.

76 D. Delia, "The population of Roman Alexandria," *TAPhA* 118 (1988) 275-92.

77 Hanson 2011 and 2016 (both supra n.1).

78 Flohr (supra n.33); Storey (supra n.15) 973-74; Wallace-Hadrill (supra n.31) 203.

79 R. Meiggs, *Roman Ostia* (Oxford 1960) 532-34; Packer 1971 (supra n.62) 70; Storey (supra n.15) 974-75.

80 L. de Ligt, *Peasants, ctizens, and soldiers: studies in the demographic history of Roman Italy, 225 B.C.–A.D. 100* (Cambridge 2012).

81 L. de Ligt, "The album of Herculaneum and a model of the town's demography," *JRA* 25 (2012) 69-94.

82 Bairoch (supra n.17); Chandler (supra n.17); Erdkamp (supra n.1) 244; E. Lo Cascio, "Urbanization as a proxy of demographic and economic growth," in Bowman and Wilson 2009 (supra n.1) 87-106; Scheidel 2007 (supra n.1) 80.

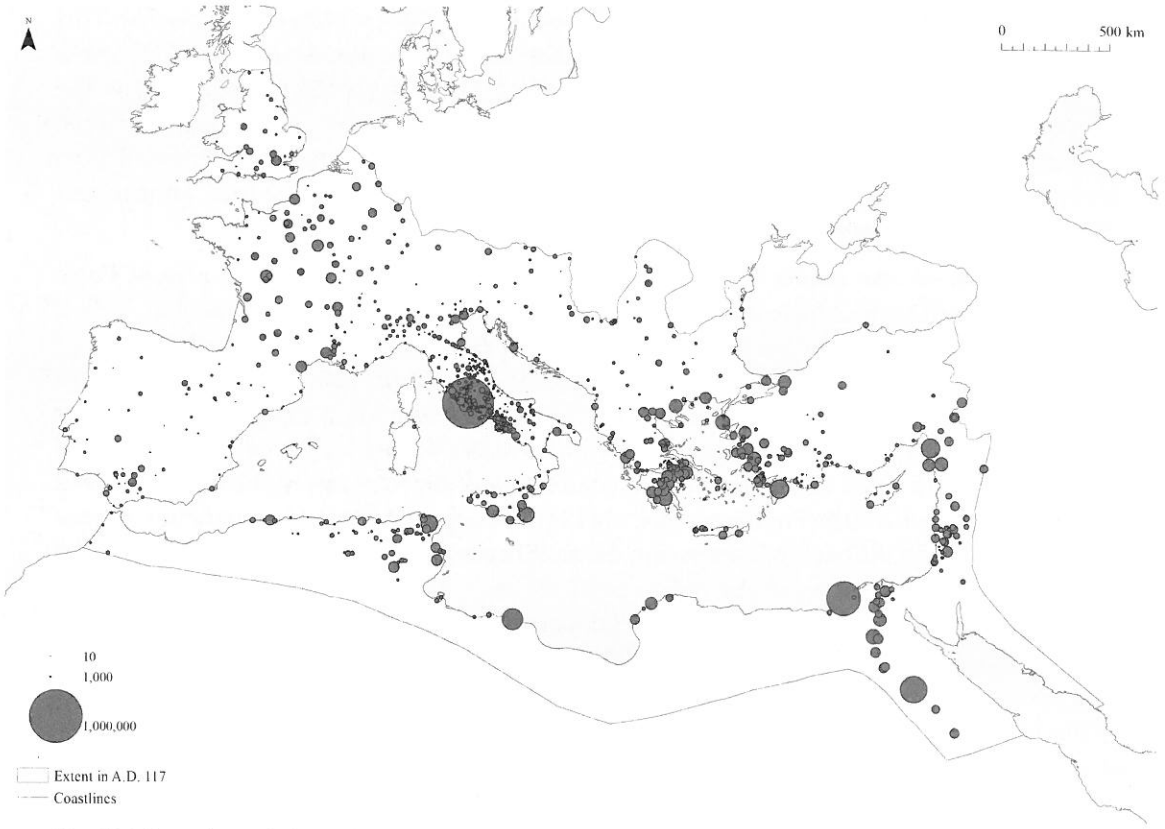

Fig. 6. Estimated populations of cities and towns in the Roman world in the Imperial age, based on the information in Hanson 2016 [supra n.1] and the present study.

As Hanson demonstrated, it is possible to measure the inhabited areas of 885 of the 1,388 settlements appearing in his catalogue of cities in the Roman world between the 1st c. B.C. and the 3rd c. A.D. (figs. 4-6).[83] These settlements range in size from 1,783 ha to less than 1 ha but averaged about 54 ha. Although these measurements were often based on defensive structures, including walls, wherever feasible other features were also used (e.g., urban grids, the locations of monumental structures, residential areas, cemeteries, and even natural features such as changes in relief, rivers, and coastlines). If we apply the equation described in this article to each site and take the sum of the results, it suggests an overall urban population of at least 9 million with a threshold of 5,000 individuals, and at least 10 million with a threshold of 1,000 individuals. As Hanson noted, since we have areas for only about two-thirds of the settlements in the catalogue, this raises the issue of whether we can make suggestions about the approximate magnitude of the others.[84] As he argued, although the most important settlements are more likely to have been found and recorded, they are also more likely to have been obliterated by later developments, meaning that the chances of having information about different classes of settlement should be relatively even. If this is correct, it means that we can assume that the sites for which we have evidence represent a relatively random sample, and can scale it up accordingly. This suggests that the overall urban population must have been in the region of at least 14

83 Hanson 2016 (supra n.1).
84 Ibid.

million (with the 5,000 threshold) or 15 million (with the 1,000 threshold). This is almost double the figure of 7 to 9 million referred to above.[85] It is also substantially more than the figure of either 7.4 or 10.4 million recently given by Wilson (also based on the area x density method, but he had access only to a limited number of measurements of inhabited areas and used a broad range of figures for their population densities).[86]

As E. Lo Cascio has pointed out, if the total urban population of the Roman world is larger than normally thought, then

> either the rate of urbanization must have been higher than 10% for the empire at large, a figure often proposed, or the population of the empire must have been larger than 50 to 60 million, the figure advocated by most ancient historians.[87]

Our results support this observation, since they either indicate that the urbanization rate must have been closer to *c.*25-30% (to be consistent with the estimate for the total population) or that the total population must have been closer to 150 million (to be consonant with the estimate for the urbanization rate). In either case, these findings have significant implications for our understanding of the demographic conditions of the ancient world, since they indicate that either the urbanization rate or the total population was much more developed than we would expect, compared with the information for later periods that is supplied by Chandler or Bairoch (Table 7).[88]

TABLE 7

ESTIMATED NUMBER OF CITIES, URBAN POPULATION, TOTAL POPULATION, AND URBANIZATION RATE (threshold of 5,000 individuals) OF EUROPE BETWEEN A.D. 800 AND 1900 (based on Bairoch 1988 [supra n.17] Tables 7.1, 8.2, and 13.2)

Date	*Number of cities*	*Urban population in millions*	*Total population in millions*	*Urbanization rate (%)*
800	77	2.2	32.0	6.9
1000	111	3.8	39.0	9.7
1300	242	7.9	75.0	10.5
1500	241	8.2	76.0	10.7
1600	294	10.9	95.0	11.5
1700	330	12.6	102.0	12.3
1800	-	18.6	154.0	12.1
1900	-	108.3	285.0	38.0

Conclusions

In this paper we reviewed earlier attempts to estimate the populations of ancient settlements based on various kinds of textual and archaeological evidence and have summarised more recent attempts to estimate the populations of such settlements by measuring their inhabited areas and multiplying these by ranges of population densities. We then discussed current attempts to model the relationship between the inhabited areas, population densities, and populations of modern settlements in mathematical form. We explored whether it is possible to identify the same relationship in ancient settlements, and whether it is feasible to use it to improve on the ranges of population densities used before. To achieve this,

85 Scheidel 2007 (supra n.1) 80.
86 Wilson 2011 (supra n.1).
87 Lo Cascio (supra n.83) 97.
88 Bairoch (supra n.17); Chandler (supra n.17).

we gathered new information about the numbers of residential structures in a sample of 52 sites, proposed a figure for their average number of inhabitants, estimated their populations, and divided these figures for the total population by the area that was studied to generate new evidence for their population densities. The results suggest that there are strong relationships between the inhabited areas, population densities, and populations of these sites that are consistent with the models alluded to above. This relationship can be captured in a simple equation, which enables us to predict the populations of some of the best-known settlements such as Rome, Alexandria, Antioch, Carthage and Ephesus, as well as Pompeii, Herculaneum and Ostia, with remarkable exactness. This suggests that it could be used to estimate the populations of other settlements so long as we have evidence for their inhabited areas. It enables us to use existing information to come up with a new estimate for the overall urban population, allowing one to make some new suggestions about the urbanization rate and the total population.

This approach has great potential beyond the specific application presented here, since it could be applied to the rest of the settlement hierarchy, including villages and hamlets, so long as some additional information could be found to calibrate the relationship between inhabited areas and population densities for smaller sites. This would open up significant new areas of research, since it would allow one to estimate both the urban population and the rural population, in turn allowing scholars to come up with more concrete evidence for the urbanization rate and total population of the ancient world.

It should also be noted that the overall relationship between inhabited areas, population densities, and populations of settlements that has been found here is consistent with the results found in other contexts in both the ancient and modern worlds. This indicates that there might be more fundamental commonalities between the urbanism of the ancient and modern worlds than have been recognized so far, which would raise interesting questions about our understanding of the development of urbanism over the *longue durée*.

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