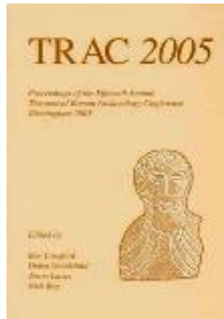

Paper Information:

Title: Modelling Roman Demography and Urban Dependency in Central Italy
Author: Helen Goodchild
Pages: 42–56

DOI: http://doi.org/10.16995/TRAC2005_42_56
Publication Date: 24 March 2006

Volume Information:

Croxford, B., Goodchild, H., Lucas, J., and Ray, N. (eds) 2006. *TRAC 2005: Proceedings of the Fifteenth Annual Theoretical Roman Archaeology Conference, Birmingham 2005.* Oxford: Oxbow Books

Copyright and Hardcopy Editions:

Modelling Roman demography and urban dependency in central Italy

Helen Goodchild

Introduction

Agricultural landscapes formed the backbone of the Roman Empire, supporting the army and urban centres, not least the metropolis of Rome itself. As such, the Roman economy is a highly complex subject, tied in with themes such as food supply, manpower, and the relationships between towns and their hinterlands (see for example Brunt 1971; Hopkins 1978; Morley 1996; Garnsey 1998). Agricultural production is intrinsically linked to population as, obviously, the more food produced, the more people that could be supported. Roman demography has been a major theme since the late nineteenth century, with estimates of population density for Roman Italy ranging widely, from around 13 up to 67 persons per square kilometre (e.g. Beloch 1886; Lo Cascio 1999). In this period it has also been estimated that between 65–90% of the population was engaged in agriculture (Jongman 1988: 65; Hopkins 1978: 6) and, although it would appear that the vast majority of the Roman population was involved in food production, they also had to produce enough surplus to support a non-agriculturally-oriented population.

It has been suggested that most towns would have been locally supplied, through rents or other exchange mechanisms, and only major surpluses or shortages would instigate more long distance trade (Hopkins 1980, 101-102; Jongman 1988, 78-79, 131; de Ligt 1990, 35ff). The productive potential of an area is therefore very important, and would dictate how many people could have lived in both town and country without recourse to imports. Urban expansion cannot occur without a stable economic base as it requires a constant supply of both resources and people (Hordern and Purcell 2000, 111; Woods 1989). The existence of a network of towns across Italy, supplied by taxes, rents and trade, would therefore seem to suggest that Roman agriculture was capable of producing a sizeable surplus. Within the models presented here it may be demonstrated that productivity would need to be high in order to produce enough surplus to support the local urban populations.

The creation of a huge dataset for the Middle Tiber Valley enables us to model the potential food supply and the subsequent supported population of this area. It also enables us to gauge whether or not there was likely to have been any surplus with which to feed non-productive populations. From this surplus we may also be able to judge the potential size of the urban population in this area.

The data available consisted of Roman site locations from the South Etruria surveys and geographic data from the British School at Rome's Tiber Valley Project (Potter 1979; Patterson and Witcher 2002; Patterson 2004; Patterson *et al* 2004; Kay and Witcher 2005) alongside information from a number of ancient sources. The study area itself is around 2600 square kilometres in size and consists of the two regions of South Etruria and Sabina on either side of the Tiber, to the north of Rome (see Fig. 1). The aim of the analysis was to use these data to compare model yields from notional farms within a GIS.

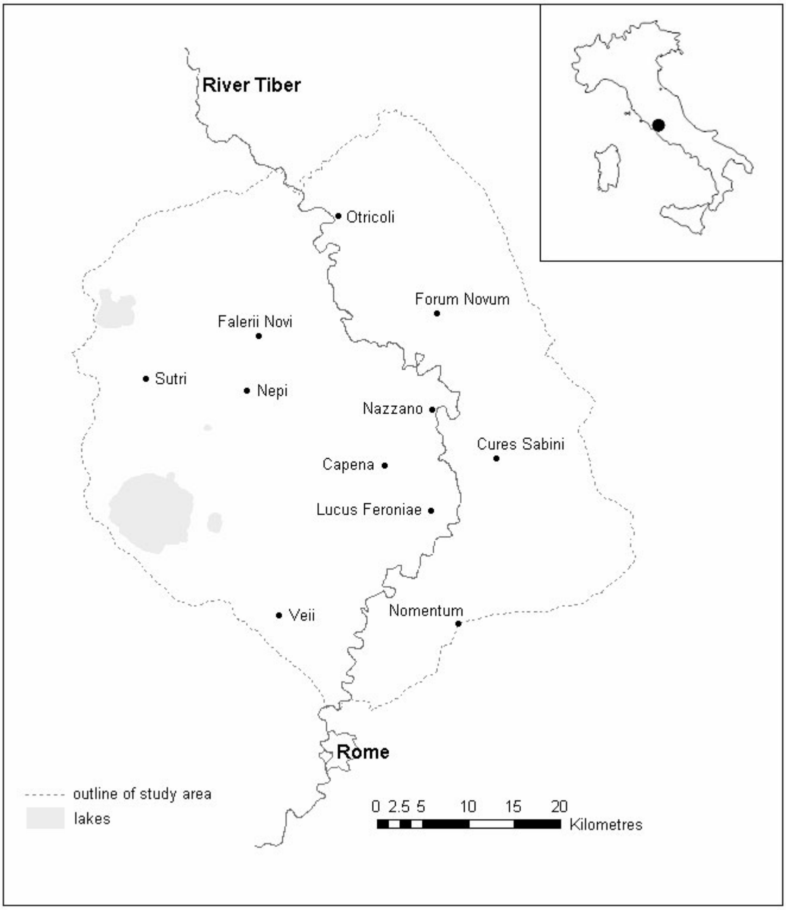

Figure 1: The Tiber Valley study area (British School at Rome)

The basic methodology for estimating supported population from these sites was firstly to create a yield map to calculate the kilograms per hectare of wheat produced and convert this to its calorific equivalent. Wheat was used because it is thought to have made up a large percentage of the ancient diet (see Cato *de Agr*. 56; Jongman 1988, 79–80; Foxhall and Forbes 1982, 74; Garnsey 1999, 12). Then, the next stage was to establish the annual nutritional requirements of the population, and divide the available calories by the nutritional requirement to derive the supported population. This could then be compared to the estimated population densities posited by scholars of ancient demography for Roman Italy, and any surplus calculated.

This type of modelling, of course, has its limitations and it must be stressed here that the models presented are not claiming to be 'agricultural truth' for the period in question. Instead what are being presented are a series of investigations into the ancient sources and their effects on existing demographic models when applied to the area of the middle Tiber Valley. They provide an insight into the nature of surplus production and how urban structures may have been supported in the Early Imperial period.

Modelling the carrying capacity of farms and villas

Our main sources for Roman agricultural production are the works of the agronomists. In Cato (*de Agr.*), Varro (*Rust.*) and Columella (*Rust.*), as well some references from Pliny the Elder (*HN*), we have numerous allusions to yields and sowing rates, as well as to the working year of an agricultural enterprise. Using figures from these sources enables us to test the implications of these statements, and whether they are reliable within the study area, and the range of population figures we may expect.

The most useful information for these models from the ancient sources is the productivity of wheat in this period. The yield most frequently used in calculations of production and population is the wheat yield of 4:1 given by Columella (*Rust*. 3.3.4) for the whole of Italy (see Brunt 1971; Hopkins 1978; Jongman 1988). This is the lowest of the yields given in antiquity, and other yields range from around 8 to 15:1 (Varro *Rust* 1.44.1; Cicero *Verr* 2.3.112) with some exceptional yields of 100:1 given for Sicily (Varro *Rust*. 1.44.1; Pliny the Elder *HN* 18.94-5). For the study area, Varro speaks of Etruria specifically as producing yields of between 10 and 15:1(*Rust* 1.44.1).

The reliability of these yields have been discussed at length by various scholars (for example White 1963; 1970; Brunt 1972; Evans 1981; Duncan-Jones 1982). White, for instance, argued that similarities between early twentieth century yields for Sicily and Tuscany, and the Roman yields of Varro and Cicero (between 8 and 15:1) demonstrated their reliability. This was rejected by Brunt, and he stated that Columella's yield of 4:1 was a more appropriate average for Italy as a whole, given the variety of fertility across the country.

In the models presented here, a range of yields, sowing rates and fallowing regimes, amongst other variables, were used in order to gauge a range of possible production figures. Yields of 4:1, 8:1 and 15:1 were tested with plots of different sizes, using a standard sowing rate of 5 *modii* per *iugerum* (approximately 135 kilos per hectare) in order to test the effects of these different wheat yields on the potential supported population.

References to plot sizes in antiquity occur in a variety of contexts. These vary from casual remarks, to detailed information regarding the plots of veteran settlers. All of these known references to plot sizes were used to gauge the range of potential plots sizes for the area. Sizes ranged from the historic *heredium* of two *iugera* (approximately ½ hectare; Varro *Rust.* 1.10.12) up to large agglomerated landholdings of over 200 *iugera* (50 hectares; Cato *de Agr*. 10), and even some unusual examples of enormous estates of around 400,000 *iugera* (Brunt 1975), although these massive estates were not used within the model.

The next stage was to assess likely deductions for seed, potential losses and fallowing. As we used a 5 *modii* per *iugerum* sowing rate for the yields, a higher rate of 8 *modii* was used to cover for any potential losses. Losses through crop failure, or deterioration whilst in storage through pests or disease could be enormous. To illustrate, for ancient Greece it has been estimated that losses could be as high as 50–80% (Gallant 1991, 97–98), but this could be due to the likelihood of regular crop failure in this region and other environmental variables. This range of figures has been stated as being far too high for the ancient Mediterranean (Forbes and Foxhall 1995, 74), and anthropological comparisons have shown that losses in storage could actually be reduced to as little as 5% (Clark and Haswell 1970, 62). For the model, as well as the buffer for the seed, an additional 10% loss was added. This is a typical amount of loss from processing and household wastage (Clark and Haswell 1970, 57–58).

A range of fallowing regimes as well as crop rotations are attested in the sources. Complete cultivation of all areas in successive years is not often viable in an agricultural landscape, as it would result in the soil quickly losing its fertility and becoming barren. Although it has been stated that some areas of Etruria were cropped continually (Varro *Rust*. 1.44.2-5), it is more likely that some sort of rotation or fallowing took place. This could vary from straightforward 50% fallow to more complex rotations involving legumes or other nitrogen fixers (Pliny *HN* 18.91, Columella *Rust* 2.17.4, Virgil *Georgics* 1.73ff). The four systems modelled were continual cropping, one-quarter fallowed, half fallowed and three-quarters fallowed.

For the basic model, nutritional requirements were set at 250 kilograms per person per year. Hopkins (2002; 1978) sets this as minimum subsistence in his own models, allowing 220 kilograms or 2000 calories per day for food, with an additional 30 kilograms of wheat equivalent annually for clothing, heat and housing.

Table 1: Number of people supported using notional territories

Yield		Number of people supported							
		2 *iug.*	5 *iug.*	10 *iug.*	12 *iug.*	20 *iug.*	40 *iug.*	100 *iug.*	240 *iug.*
15:1	continual cropping	3	8	17	20	34	68	169	405
	1/4 fallow	3	6	13	15	25	51	127	304
	1/2 fallow	2	4	8	10	17	34	84	203
	3/4 fallow	0.8	2	4	5	8	17	42	101
8:1	continual cropping	2	4	8	10	17	33	84	201
	1/4 fallow	1	3	6	8	13	25	63	151
	1/2 fallow	0.8	2	4	5	8	17	42	100
	3/4 fallow	0.4	1	2	3	4	8	21	50
4:1	continual cropping	0.7	2	4	4	7	14	35	84
	1/4 fallow	0.5	1	3	3	5	11	26	63
	1/2 fallow	0.4	1	2	2	4	7	18	42
	3/4 fallow	0.2	0	1	1	2	4	9	21

Results from this basic model show that only plots of over 20 *iugera* for low yields, and over 5 *iugera* for higher yields would produce enough to sustain a household of around 6–8 people (Table 1). This, however, presupposes that farms had no access to alternative food sources, for example by foraging or the use of communal lands, or extra income through seasonal labour for larger landowners. This model also takes no account of any surplus. Assuming that there was a local urban population to feed, this would mean that, with the low 4:1 yield, only the large villa estates could have produced a surplus to help support urban populations. With the higher yields, however, this could be done by farms of over 10 *iugera*, with little or no fallow.

Creating the production map according to sources

Assuming such regular yields across a region is problematic, however, as even small regions are subject to significant local variation in return. Therefore the next stage was to refine this basic model and to assess potential production within a GIS. The geographical data was modelled in relation to the sources to produce a map showing the most suitable areas for arable agriculture. The variables used included slope, aspect, distance to water, as well as the productive potential of the underlying geology. The most suitable areas were those on volcanic geology, on south-facing slopes of under 15%, in close proximity to water. This was based on passages by Cato (*de Agr*. 1.2–4) and Columella (*Rust*. 1.2), where they describe the best areas for farming as fitting these criteria.

The most suitable areas were given the highest yield of 15:1, in order to test the implications of Varro's statements about the fertility of Etruria, whilst less suitable areas were given progressively lower returns (Fig. 2). In this way it is possible to see how many people known sites in the study area could potentially support, and whether certain plot sizes mentioned in sources were likely to have been economically viable in this region. Two alternative yield maps of 8:1 and 4:1 were also created to test the effects of lower yields in this area. The known sites from the South Etruria database were compared to see whether or not they were situated on areas suitable for arable agriculture, and how much food these areas could potentially produce.

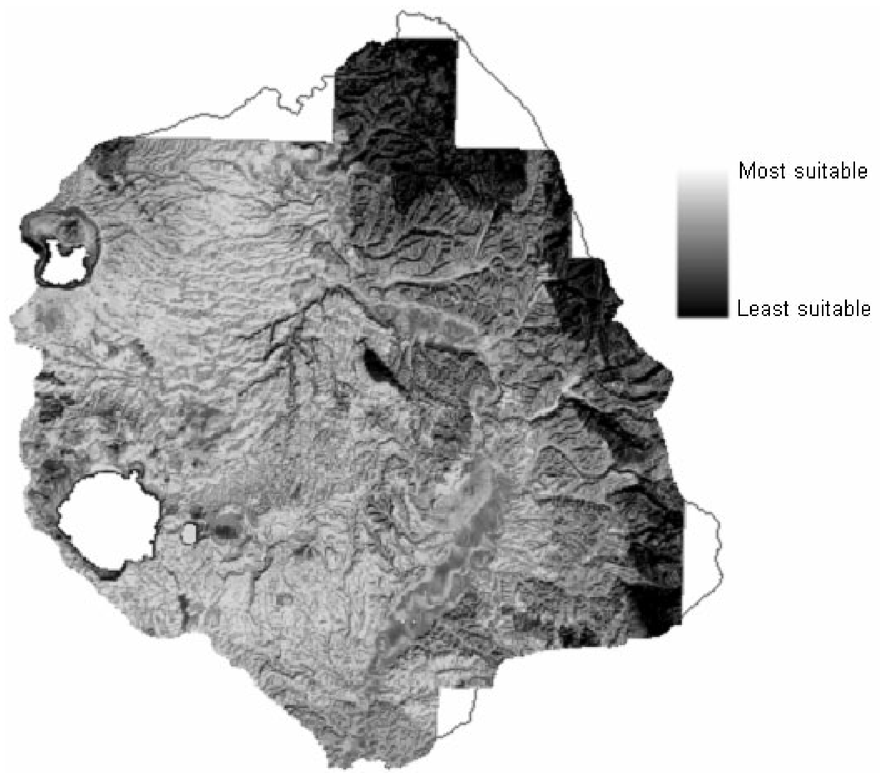

Figure 2: Arable production map with a maximum yield of 15:1

Once the sites had been overlaid, it was then necessary to determine what size of area each site potentially exploited. Distances between rural sites were graphed in the GIS to determine if potential territories were comparable to those from the sources used in the first model. Based on the minimum average distances between sites, if each site were given buffers, territories for farms would be approximately 12 *iugera* in size, or 3 hectares, which is comparable to those in the sources. Villas, however, would only be about 40 *iugera* or 10 hectares. This small territory is due to the incredibly dense settlement in the area north of Rome. It is possible, of course, that many of the smaller farms may have been tenants of larger landlords in the area, thereby increasing the size of the area controlled by the villa owners. Alternatively, however, it could be that villas in this area were dedicated to specialised production for the market in Rome, which require significantly less area for cultivation.

Looking at the area with the buffers overlaid, we see that there is little or no overlap between the larger sites, but we are also seeing a lot of unexploited land. As an experiment, a larger territory of 100 *iugera* (based on Cato's *vinea*; *de Agr*. 11.1–2) was given to all villas. Both of these can be seen in Figures 3 and 4. Of course this means a certain amount of overlap in some areas, which we can see here, but in general these sites were reasonably well separated for a model such as this, and provide an opportunity to test the implications of the plot sizes from the sources.

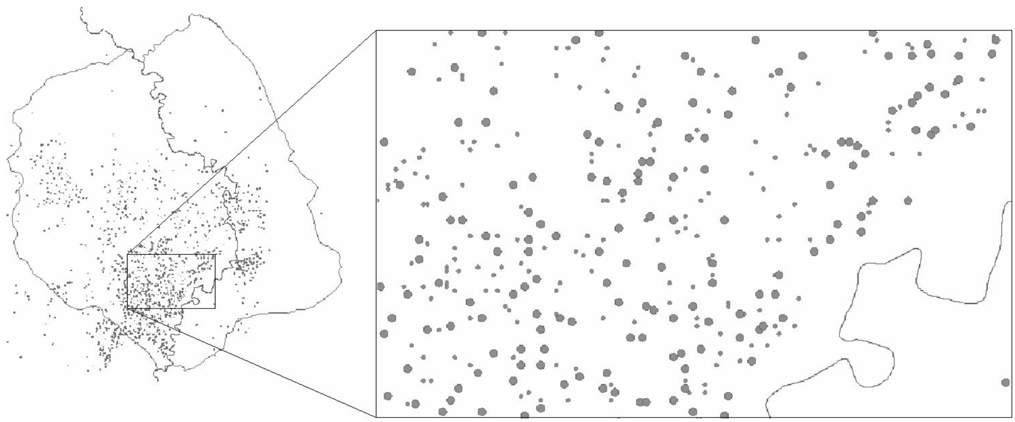

Figure 3: Detail of South Etruria showing 12 iugera farms and 40 iugera villas

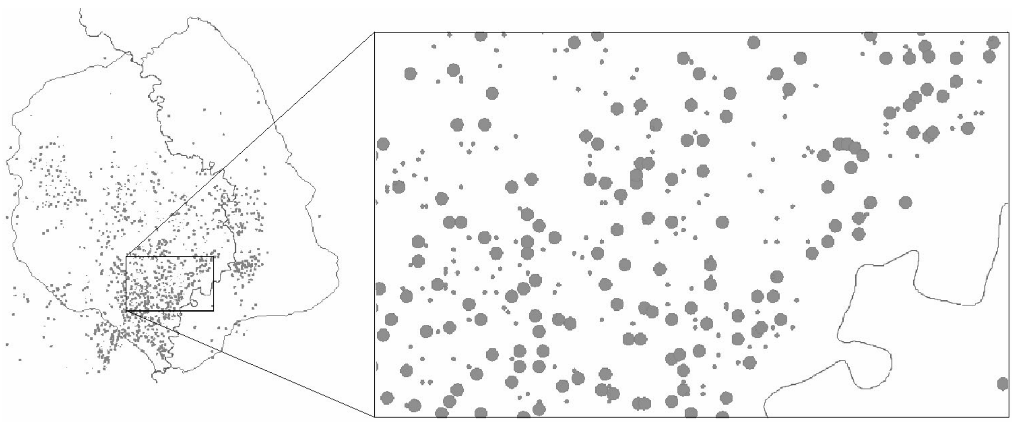

Figure 4: Detail of South Etruria showing 12 iugera farms and 100 iugera villas

It is unlikely, of course, that these territories will have been so consistent in their size. Some will have been smaller, whilst it is highly likely that many may have controlled larger areas, including some of the farms in their vicinity. We are also making assumptions about the shape of the cultivated area. By assuming a circular territory, we do not take into account the possibility of either square centuriated plots (see Campbell 2000; Dilke 1971) or any other configuration of landholding. The villa or farm need not lie in the centre of the plot, or the area cultivated may not even have been proximate to the central residence. More importantly, by separating rural sites into two distinct categories – small farms and large villas – we are hiding much of the variation in rural settlement.

To illustrate, an earlier model utilised differentially sized buffers for each rural site. The distance between each site was measured and a buffer constructed based on the proximity of the nearest site (Fig. 5). This created a coverage that, although it reflected diversity in plot size, also carried with it the same drawbacks as a territory based on Thiessen polygons. The coverage gave sites around the edges of the study area, or those near un-surveyed areas, unrealistically large territories. Also, as field survey is known to only recover a fraction of sites, it was considered that this type of coverage disregarded the likelihood of other sites in the area, and allocated the majority of the available territory. With this in mind, the model sizes chosen – 12 *iugera* for farms and 100 *iugera* for villas – are useful standards with which to gauge a model production figure for the area. This enables us to test the historical sources and, of course, a variety of different sized and shaped territories may be modelled at any time, thereby giving a range of production figures for the area.

Figure 5: Coverage showing buffers based on proximity of nearest site (b. overlaid with surveyed areas)

Once the production map and the exploited territory were established, the next stage was to determine how much food these areas potentially produced, and how many people this could support. Hopkins' minimum subsistence model of 250 kgs (approximately 2300 calories per day including the additional allowance for heat, clothing, etc.) was compared to data from the historical sources. Columella (*Rust.* 2.7.8–9) outlines the number of days per year spent on certain agricultural tasks and this, alongside data from the Food and Agriculture Organization of the United Nations (FAO), indicates that an agricultural labourer would require 3115 calories per day for an adult male. Of course, this is subject to many variables, such as stature, gender, age, and the fact that not everyone on a farm necessarily had consistently the same workload or metabolic rate.

Table 2: Energy required for Columella's working year based on FAO 1985 Tables 9-11

Columella's working year	Energy level	Days	Energy requirement in kcal
Main agricultural tasks	Heavy	190	652080
Bad weather / holidays	Moderate	30	85800
Rest after sowing	Light	30	70200
Remaining days	Moderate	115	328900
Total annual energy requirement			1136980
Daily requirement			3115

These calculations also assume that the average Roman farm worker actually *received* their recommended daily requirements. Obviously in times of shortage, or even on a daily basis if one were operating at a subsistence level, people would not always necessarily receive enough food to retain good health. Hopkins' model only allows for enough food for survival, and he states that at this rate of consumption, most people would feel hungry and lethargic (Hopkins 2002, 197 n.11). However, the figure of 3115 calories does provide a good model for use here, particularly as Hopkins does not take into account variables such as the consumption of wheat by draught animals or horses. Also, although many may have survived at such a low subsistence rate, this would not have been the case for all the population.

Once an average nutritional requirement was ascertained, the yield map was analysed to give an absolute maximum production figure for the area, disregarding any particular plots. These results showed that, although the scenario is very unlikely, should the *entire* study area be cultivated with cereals at a maximum yield of 15:1, it was capable of supporting around 750,000 people at a very high density of around 275 persons per square kilometre (Table 3). This, of course, takes no account of factors such as uncultivated areas like woodland or urban centres, the reservation of seed for next year's crop, any loss during processing or through pests, as well as agricultural practices like fallowing. These factors were then incorporated into the model, along with a higher sowing rate and the other yield ratios, and the wide range of results are shown in Table 3.

Table 3: Supported population density for the area, assuming total cultivation

Sowing rate	Maximum Yield	Population density per km^2			
		Continual cropping	1/4 fallow	1/2 fallow	3/4 fallow
5 *modii* per *iugerum*	15:1	275	206	137	69
	8:1	111	83	56	28
	4:1	34	25	17	8
8 *modii* per *iugerum*	15:1	451	338	225	113
	8:1	222	167	111	56
	4:1	99	74	49	25

To give a more realistic range of yields, the known Early Imperial sites were used as they represented the maximum site density in the area. They were given buffers according to the model plot sizes determined above – 12 and 100 *iugera*. These were then overlaid onto the yield map to show the potentially exploitable area for each site. The mean production figure for each site was then determined and the total production calculated, allowing for seed for the next year's crop and losses, as well as two fallowing regimes. As can be seen in Table 4, the population density is dramatically reduced from the previous calculations, with a maximum of only 29 persons supported per square kilometre.

Table 4: Supported population assuming territories of 12 and 100 iugera

Yield	Unit	Supported population			
		Continual cropping	1/4 fallow	1/2 fallow	3/4 fallow
15:1	Farms	7255	5441	3628	1814
	Villas	68057	51042	34028	17014
	Density per km^2	29	22	15	7
8:1	Farms	3331	2498	1666	833
	Villas	30722	23042	15361	7681
	Density per km^2	13	10	7	3
4:1	Farms	1096	822	548	274
	Villas	10404	7803	5202	2601
	Density per km^2	4	3	2	1

As stated above, previous demographic estimates for the whole country have ranged from around 13 up to 67 persons per square kilometre in the late Republic and Early Empire. It may be assumed, however, that settlement around Rome would have been denser than these Italian national averages suggest, due to the attraction of the capital and the services it provided. For comparison, the population density of Lazio (minus the city of Rome) in the mid-20th century was approximately 96 persons per square kilometre (Naval Intelligence Division 1945, 493, Fig. 31), whilst modern figures from 2001 show Lazio (minus Rome) to have increased to a population density per square kilometre of approximately 161 (ISTAT 2001, Table 2).

Comparing these figures to those of the model, we see that our maximum supported figure only compares to the lower estimates for Roman Italy. The consequences of this are striking. It implies that there would be very little surplus production with which to feed the local urban populations let alone Rome, with little or no buffer for bad harvests.

Preliminary results from these models have therefore shown that, if we are to believe the sources, the study area, although a comparatively fertile region, was not able to support a particularly large population, at a maximum of only 29 persons per square kilometre, if cultivated in the plots modelled (Table 4). However, given that a stable economic base is essential for expansion and urban development, it is unlikely that Italy was this unproductive. This would seem to imply then, that our models are underestimating the productive capacity of this area. We can propose a number of potential reasons for this:

- that larger plots were cultivated in antiquity,
- that cereal yields were higher than suggested by the agronomists,
- that low yielding areas were dedicated to alternative economies, making these areas more productive and therefore supporting a larger population,

- that people were surviving on lower rations,
- that a large percentage of the population relied on imports, or
- that settlement was far denser than is suggested by the field survey data.

Of course, this situation could also be due to any combination of these factors. Looking at the results as number of people supported per site we find a more positive figure, with a maximum of 14 people supported per farm and 105 per villa (Table 5). This indicates that, if yields were high, surplus was not only likely for villa owners, but for smaller scale farms as well, which are often assumed to produce at only subsistence level. The ability of small farmers to produce a surplus, however, is attested by the frequency of fairs and markets in the region, providing an outlet for smaller-scale exchange. These results do show, conversely, that the 'average' yield of 4:1 could not support small farmers in this model, as only a maximum of two people per farm could be fed. This does not take account, however, of other potential sources of food or income, such as seasonal hired labour.

Table 5: Number of people supported per agricultural unit

Yield	Unit	Continual cropping	1/4 fallow	1/2 fallow	3/4 fallow
15:1	Farm	14	10	7	3
	Villa	105	79	52	26
8:1	Farm	6	5	3	2
	Villa	47	35	24	12
4:1	Farm	2	2	1	1
	Villa	16	12	8	4

This leads us to believe that, contrary to the impression given by the low population density, individual units were actually productive, and it is merely the number of sites recovered in the landscape that is adversely affecting the results. The recovery of sites is a major issue within field survey and it is probable that many more undiscovered sites exist in the hinterland of Rome (see Di Giuseppe *et al*. 2002). This would significantly increase the supported population density here, as, if we had more agricultural units, production would subsequently be higher.

Surplus and urban dependency

In order to quantify the potential surplus available to an urban population, a standard household of six people per farm and twenty-five people per villa was assumed in order to calculate the rural population. The farm population was considered appropriate as this figure suggests a household of an average nuclear family. Duncan-Jones (1982, 49–50) has argued that a plot of 50 *iugera* would only need four men to work it if it were under grain, and so a smaller plot with a mixed economy would be easily cultivated with six, some of whom would have had domestic or other responsibilities (this figure is also used by Foxhall and Forbes 1982, 49).

The figure for villas was determined from the agronomists who gave numbers for the workforce of a 100 and 240 *iugera* estate. According to Cato (*de Agr*. 11) and Columella (*Rust*. 2.12.1–6), these ranged between eight and sixteen labourers, the number of workers required being dependent on the type of economy followed. However, if we assume that the estates followed the most labour intensive strategy then we may estimate the local consumption at its maximum. If we added likely household staff and the resident elite at any time, we may increase the villa population from sixteen to around twenty-five.

Applying these figures to the known sites from the Tiber Valley gave a total rural population of over 19,000. This figure was subtracted from the number supported by the original model, in order to show the number of people potentially supported by the surplus only. Assuming these production figures, Table 6 demonstrates how much surplus may have been available to agriculturally-unproductive populations of the twelve nucleated centres within the study area.

Table 6: Number of people supported by the surplus only

	Yield	Continual cropping	1/4 fallow	1/2 fallow	3/4 fallow
Total population supported by surplus	15:1 8:1 4:1	55852 14594 -7960	37024 6080 -10835	18196 -2433 -13710	-632 -10947 -16585
Population supported per town	15:1 8:1 4:1	4654 1216 0	3085 507 0	1516 0 0	0 0 0

It is clear from these results that, with the exception of the low yields and extensive fallow, the study area was generally capable of producing a large surplus, able to support a significant urban population. The 15:1 yield of Varro was capable of producing enough surplus for over 55,000 people, or over 4,600 per town in the study area (Table 6). Looking at the 4:1 yield of Columella, however, we see that the area was unable to support a large section of its rural population, let alone an urban one. This shows that the 4:1 yield of Columella is unlikely to have been the case in South Etruria as it could not produce enough to support urban growth, without significant input from external sources. It has been claimed that this particular yield is excessively low anyway, not only because it refers to a national average, but also because, as Columella is trying to encourage people into viticulture he is claimed to have played down the productivity of wheat. An alternative suggestion is that he was referring to wheat intercropped between rows of vines, thereby producing a low wheat yield, but not a low overall return per unit (Spurr 1986, 83-84; White 1963, 209).

Looking at the higher yields of 8 and 15:1, the models in Table 6 demonstrate the potential for the rural population to support a large, non-agriculturally-productive urban population, even if the population density was as low as 29 persons per square kilometre (Table 4). However, should the area be subject to any crop failures, the effect on any non-productive population would be potentially disastrous.

We cannot assume that production was always this high. Yields are not always consistent and all farmers are liable to have bad harvests and crop failures at times. From comparative evidence it has been argued that, in order to counteract the effects of bad harvests, most farmers would retain a portion of their crops in storage (Gallant 1991, 94; Clark and Haswell 1970, 62). This would mean that further reductions to the supported population must therefore be made. With fallowing, seed, extra storage for bad years, household wastage, and so forth, a large percentage of the crop is therefore lost to immediate consumption by local populations. That said, if rural settlement was significantly denser than is suggested by the field survey results, we would have a large number of additional sites likely to be producing surplus in order for urban populations to be consistently supported economically, even if some specific areas were not as productive as others, and suffered through bad weather or pestilence. We would consequently have a higher number of sites producing a slightly smaller surplus per unit.

Urban mortality is generally much higher than in rural areas, and towns rely on regular migration to maintain themselves (Woods 1989; Jongman 2003, 107). This would only have been possible if their hinterlands were producing a regular surplus, or – if the food supply was interrupted – that an alternative source was available. In this analysis we refer primarily to local, smaller centres, but of course this same argument also applies to Rome itself. However, Rome not only attracted migrants from further afield than its local hinterland, but also had greater access to food supplies from the vast reaches of the empire. Incorporating demand from Rome into this analysis is therefore a difficult process, but its effect on its hinterland – of which the study area is part – must be taken account of during interpretation.

Here we may introduce the idea of imports. As argued above, towns are generally assumed to be mostly self-sufficient, living off of the production of their territory either through taxes or rents, or by providing services and other goods in exchange. Therefore, if crops in the region gave a particularly bad return in one year, and could only feed the rural producers, it is possible that the urban residents could have relied on trade with external sources at these times. If this were the case, then longer distance trade in staple goods such as grain therefore probably only occurred during fluctuations in the size of local harvests.

So, for surplus production, it would seem that cereal cultivation in this area must have been high yielding, in the region of 8:1 or more, otherwise the local urban populations would have been heavily dependent on external sources, not under their direct control. Also, in the ancient sources, Etruria is spoken of as a major supplier of wheat, particularly throughout Rome's early history (e.g. Livy 25.15.4; 25.20.3; 25.22.5; 27.3.9), and so any shortfall here may have had major consequences for other regions reliant upon their production.

Conclusions

These models have put forward only a few of the possibilities, and there are many other variables that can be included in future analysis. It is possible that some urban dwellers may have cultivated land outside the towns, meaning that they could support themselves, without relying on the rural population. This would raise the potential surplus even higher. Also, most importantly, we know that other crops were produced in this area, and that for some crops, such as olives, vines, or with specialised production such as *pastio villatica*, the return was usually higher per unit area. Jongman (2003, 112–116) demonstrates that the calorie yield per hectare of wine and oil was approximately five times higher than that of wheat in a two-field system. This would mean that a smaller area and fewer sites would theoretically be needed in order to supply local needs. It would be an interesting avenue of research to see therefore if the supported population followed this same pattern, or whether local conditions would affect the model significantly.

It is possible to test any of these variables. For example, further production maps can incorporate other factors, such as different cultivation techniques or different economies, such as the practice of intercropping, the growing of olives, or pastoralism. This technique would also help to pinpoint the most suitable areas for these types of activities, and early results from an unpublished earlier model have shown that, whilst Etruria is very suitable for cereals, the region of the Sabina is more suited to olive cultivation than grain in many areas, due to its hillier topography and thinner soils. The model's results are supported by the ancient sources (e.g. Strabo 5.3.1; Col *Rust* 5.8.5) as well as the prevalence of olives in this area today. This is likely to affect the productive potential of the area and likely settlement attractors, and again, is likely to increase the potential surplus available. Different yield maps may also be created in order to test other historical yields. Higher settlement density may be mapped using sample sites to test the effect on production of a higher rural population, and a number of different-sized and shaped exploitable territories may also be modelled.

So, we have seen here a methodology for determining a range of potential production figures and likely surplus from ancient sources and archaeological data. This provides an insight into how agricultural production supported urban structures at this time and enabled expansion. As previously states, these are production models and not production reality, designed to test the feasibility of these different scenarios and whether or not the agricultural claims made by the Roman agronomists are possible in this particular area. As such they provide us with a range of possibilities upon which to base our interpretations of past economies, and have important implications for demographic studies of Roman Italy.

Institute of Archaeology and Antiquity, University of Birmingham

Acknowledgements

I would like to thank Helen Patterson and Andrew Wallace-Hadrill for the use of the data from the Tiber Valley Project, without which this research would not have been possible. I would also like to thank Vince Gaffney, Niall McKeown, Rob Witcher, Gareth Sears and Willem Jongman for their valuable help and advice, as well as the organisers of the TRAC session 'Roman Archaeology and Spatial Technologies' in which this paper was presented.

Bibliography

Ancient Sources

Cato (Translated by W.D. Hooper and H.B. Ash 1935). *On Agriculture*. London: William Heinemann.
Cicero (Translated by L.H.G. Greenwood 1928). *The Verrine Orations*. London: William Heinemann.
Columella (Translated by E.S. Forster and E.H. Heffner 1954) *On Agriculture*. London: William Heinemann.
Livy (Translated by F.G. Moore 1940) *History of Rome*. London: William Heinemann
Pliny the Elder (Translated by H. Rackham 1950) *Natural History*. London: William Heinemann.
Strabo (Translated by H.L. Jones 1923) *Geography*. London: William Heinemann.
Varro (Translated by W.D. Hooper and H.B. Ash 1935). *On Agriculture*. London: William Heinemann.
Virgil (Translated by H. Rushton Fairclough 1916) *Eclogues. Georgics. Aeneid, Books 1–6* London: William Heinemann.

Modern Sources

Beloch, K.J. 1886. *Die Bevolkerung der griechisch-romischen Welt.* Leipzig: Duncker & Humblot.
Brunt, P.A. 1971. *Italian Manpower 225 BC – AD 14.* Oxford: Clarendon Press.
Brunt, P.A. 1972. Review of K.D. White, Roman Farming. London: Thames and Hudson, 1970. *Journal of Roman Studies* 62: 153–158.
Brunt, P.A. 1975. Two Great Roman Landowners. *Latomus* 34(2): 619–635.

Campbell, B. 2000. *The Writings of the Roman Land Surveyors: Introduction, text, translation and commentary*. Journal of Roman Studies Monograph No. 9 London: The Society for the Promotion of Roman Studies.

Clark, C. and Haswell, M. 1970. *The Economics of Subsistence Agriculture*. London: Macmillan.

de Ligt, L. 1990. Demand, Supply, Distribution: The Roman Peasantry between Town and Countryside: Rural Monetization and Peasant Demand. *Münstersche Beiträge zur antiken Handelsgeschichte* 9(2): 24–56.

Di Giuseppe, H., Sansoni, M., Williams, J. and Witcher, R. 2002. The *Sabinensis Ager* revisited: A field survey in the Sabina Tiberina. *Papers of the British School at Rome* 70: 99–149.

Dilke, O.A.W. 1971. *The Roman Land Surveyors. An Introduction to the Agrimensores*. Newton Abbot: David and Charles.

Duncan-Jones, R.P. 1982. *The Economy of the Roman Empire: Quantitative Studies*. (2nd edn.) Cambridge: Cambridge University Press.

Evans, J.K. 1981. Wheat production and its social consequences in the Roman world. *Classical Quarterly* 31(ii): 428–442.

FAO 1985. *Energy and Protein Requirements*. Food and Agriculture Organization of the United Nations.

Forbes, H. and Foxhall, L. 1995. Ethnoarchaeology and Storage in the Ancient Mediterranean. In M. Dobson (ed.) *Food in Antiquity*. Exeter: University of Exeter Press: 69–86.

Foxhall L. and Forbes, H.A. 1982. Sitometreia: The Role of Grain as a Staple Food in Classical Antiquity. *Chiron* 12: 41–90.

Gallant, T. 1991. *Risk and Survival in Ancient Greece. Reconstructing the Rural Domestic Economy*. Cambridge: Polity Press.

Garnsey, P. 1998. *Cities, Peasants and Food in Classical Antiquity. Essays in social and economic history*. Cambridge: Cambridge University Press.

Garnsey, P. 1999. *Food and Society in Classical Antiquity*. Cambridge: Cambridge University Press

Hopkins, K. 1978. *Conquerors and Slaves. Sociological studies in Roman history Volume 1*. Cambridge: Cambridge University Press.

Hopkins, K. 1980. Taxes and Trade in the Roman Empire. *Journal of Roman Studies* 70: 101–125.

Hopkins, K. 2002. Rome, Taxes, Rents and Trade. In S. von Reden (ed.) *The Ancient Economy*. Edinburgh: Edinburgh University Press.

Hordern, P. and Purcell, N. 2000. *The Corrupting Sea*. Oxford: Blackwell Publishers.

ISTAT 2001. Popolazione residente censita al 2001 (popolazione legale) e al 1991, differenze e densità abitativa, per ripartizione geografica. *14° Censimento Generale della Popolazione e delle Abitazioni*. http://dawinci.istat.it/daWinci/ (accessed 15/10/2005).

Jongman, W. 1988. *The Economy and Society of Pompeii*. Amsterdam: J.C.Gieben.

Jongman, W. 2003. Slavery and the growth of Rome. The transformation of Italy in the second and first centuries BCE. In G. Woolf (ed.) *Rome the Cosmopolis*. Cambridge: Cambridge University Press: 100–122.

Kay, S. and Witcher, R. 2005. The Tiber Valley Project. The Role of GIS and Databases in Field Survey Data Integration and Analysis. *Archeologia e Calcolatori* 16: 113–137.

Lo Cascio, E. 1999. The Population of Roman Italy in Town and Country. In K. Sbonias (ed.) *The Archaeology of Mediterranean Landscapes 1: Reconstructing Past Population Trends in Mediterranean Europe (3000 BC – AD 1800)*. Oxford: Oxbow Books: 161–171.

Morley, N. 1996. *Metropolis and Hinterland. The City of Rome and the Italian Economy 200 BC – AD 200*. Cambridge: Cambridge University Press.

Naval Intelligence Division 1945. *Italy. Volume 2* London: Royal Admiralty Geographical Handbook.

Patterson, H. (ed.) 2004. *Bridging the Tiber: approaches to regional archaeology in the middle Tiber valley*. Archaeological Monograph of the British School at Rome 13. London: British School at Rome.

Patterson, H. and Witcher, R.E. 2002. The Tiber and Rome Through Two Millenia. In B. Mater (ed.) *New Developments in Italian Landscape Archaeology: Theory and methodology of field survey, Land evaluation and landscape perception, Pottery production and distribution. Proceedings of a three-day* *conference held at the University of Groningen, April 13–15, 2000*. B.A.R. International Series 1091 Oxford: Archaeopress: 87–90.

Patterson, H., Di Giuseppe, H., and Witcher, R. 2004. Three South Etrurian Crises: First Results of the Tiber Valley Project. *Papers of the British School at Rome* 72: 1–36.

Potter, T.W. 1979. *The Changing Landscape of South Etruria*. London: Paul Elek.

Spurr, M.S. 1986. *Arable Cultivation in Roman Italy c.200 BC – c.AD 100*. Society for the Promotion of Roman Studies: Journal of Roman Studies Monographs No. 3.

White, K.D. 1963. Wheat Farming in Roman Times. *Antiquity* 37: 207–212.

White, K.D. 1970. *Roman Farming*. London: Thames and Hudson.

Woods, R. 1989. What would one need to know to solve the 'natural decrease in early modern cities' problem? In R. Lawton (ed.) *The Rise and Fall of Great Cities. Aspects of Urbanization in the Western World*. London: Bellhaven Press: 80–95.