MODELLING ROMAN AGRICULTURAL PRODUCTION IN THE MIDDLE TIBER VALLEY, CENTRAL ITALY

By

HELEN GOODCHILD

A thesis submitted to
The University of Birmingham
For the degree of
DOCTOR OF PHILOSOPHY

Institute of Archaeology and Antiquity
School of Historical Studies
The University of Birmingham
April 2007

ABSTRACT

This thesis analyses the potential agricultural production of the regions of South Etruria and Sabina, north of Rome in the Middle Tiber Valley, Central Italy. Historical evidence from Roman authors is combined with archaeological evidence from field survey and geographical resource data, and modelled within a Geographical Information System. Farm size and location are investigated in order to determine any correlation with contemporary Roman recommendations. Multi-criteria evaluation is then used to create suitability maps, showing those regions within the study area best suited to different types of crops.

A number of different models for agricultural production within the study area are presented. Many variables are utilised, each presenting a range of possibilities for the carrying capacity of the area, complementing previous studies of demography. Research into workload, nutrition and crop yields provides a basis for determining the supported population of the area.

Urban provisioning is investigated also, showing how high yielding models could have supported a large urban population within the studied region, as well as its potential contribution to the food supply of Rome. This analysis showed which agricultural systems could adequately supply urban centres, and highlighted those models that would have led either to an urban dependency on larger scale trade networks or to decline.

ACKNOWLEDGEMENTS

This research would not have been possible without the time I spent working as a Research Assistant at the British School at Rome, 1999-2001, and I would like to thank Helen Patterson and Andrew Wallace-Hadrill for allowing me to use the data from the Tiber Valley Project. Other colleagues from the Tiber Valley Project are thanked also for their feedback on presentations I gave during my research.

The University is acknowledged for providing financial support via School of Historical Studies and Francis Corder Clayton Scholarships. I thank my supervisors Vince Gaffney and Niall McKeown for surviving the long haul, as well as Rob Witcher for his help and support.

I would like to thank my Birmingham colleagues, in particular Lisa Alberici, David Bukach, John Carman, Simon Fitch, Gareth Sears, David Smith, and Meg Watters. In particular I am indebted to Mary Harlow, for both her moral support and for her undergraduate lectures that inspired me to become a Romanist. I'll get you back one day…

Last but not least, for putting up with my endless moaning, paranoia, defeatism and deteriorating mental state I would like to thank Liam and the Goodchild clan – Mum, Dad, Stef, Rachel, Jude, Noah and Holly. Any errors or omissions are entirely the fault of Bill Gates.

CONTENTS

FIGURES

TABLES

APPENDICES

1 MODELLING THE PRODUCTIVE LANDSCAPES OF THE MIDDLE TIBER VALLEY

1.1 Introduction

Landscapes played a fundamental role in the development of ancient societies. This is because the size of a population is related to its surroundings and how much food it controls, either directly through agriculture and animal husbandry, or indirectly through imports and other trade or tax mechanisms. In the case of Rome, the city controlled vast areas beyond peninsular Italy (e.g. Witcher 2005) and could therefore call upon resources external to local productive conditions. However, the hinterland was a different matter in that it was extremely likely that local production held a far greater importance in both the rural areas and local urban centres. With this in mind, a study of agricultural systems in the hinterland north of Rome was carried out. The modelling of agricultural production and subsistence regimes allows the investigation of potential food supply (and surplus), and its effect on the demography of the area. Important questions to be approached include how were the structures of urban society supported by their rural hinterlands? Was the regional agricultural base sufficient to develop such structures without recourse to imports or alternative production strategies? How would years of low production affect non-productive members of the population?

Despite the relatively recent proliferation of large-scale surface surveys in Italy (see Chapter 2), landscape studies have tended to focus on aspects such as settlement patterns and urbanisation, often overlooking the details of how these settlements subsisted. Since the time of Malthus (1798) it has generally been accepted that there is a relationship between populations and the productivity of the areas sustaining them. Although complex societies such as the Roman Empire had recourse to imports from productive areas such as Egypt or Sicily, in this thesis the probable carrying capacity of the study area is used to estimate the maximum potential population supported by local production only (see for example Hopkins 1980: 101-102; Jongman 1988: 78-79, 131; de Ligt 1990: 35ff). The carrying capacity of an area is, of course, only the potential of the area. However, by using known site distributions and a range of site territories for farms and villas, this technique can be used to calculate the supported population for each known site. The density of sites may thereby provide important insights into land use intensity at that time. Such analysis also allows investigation into the likely longer-distance supply networks that may have been in operation to provide for any shortfalls in staple products or to provide goods not available locally.

This thesis is, in essence, an exploration of the data available from a variety of sources with a view to gauging their use within quantitative analysis. Though exploratory in nature, the fundamental aim of this study is to establish models of agricultural production for use in creating 'realistic' demographic estimates for the region. Roman demography is a highly debated field in Italy and previous estimates are broadly divided into two camps – the 'low counters' and the 'high counters'. Low counters include scholars such as Beloch, Brunt and Hopkins who estimated population densities of around 20-28 people/km^2 for the whole of Italy (Beloch 1886: chap. 8, in Lo Cascio 1999: 162; Brunt 1971a: 124ff; Hopkins 1978: 7), whilst the high counters include Frank and Lo Cascio whose estimates were higher with densities of 50-64 people/km^2 (Frank 1924: 340; Lo Cascio 1999: 166ff).

Estimating the total population of Roman Italy is not an easy task and, as evidenced by the range of estimates briefly outlined above, there is still no real consensus on the matter. The majority of these estimates are based on literary and epigraphic evidence, and little time has been given to models of carrying capacity (such as approached here) as realistic contributions to the debate. The current position, though far from being a consensus, leans towards the low estimates. To illustrate, one recent study (Witcher 2005; see also Chapter 8) used field survey data to estimate the population of the Roman suburbium. Witcher did not argue for or against the low count per se but, despite his calculations producing a high population density of c.60km in the area adjacent to Rome, this was lower in the surrounding region at a density of 42 persons/km^2, and would therefore necessarily lower the average density still further if the entire peninsula were to be assessed (Witcher 2005: 126-130). Lo Cascio, on the other hand, has proposed a variety of estimates for the Italian population, though these all remain in the 'high count' bracket (e.g. Lo Cascio 1994; 1999). His current estimate for the Augustan period, based on literary and epigraphic sources, is between 15-16 million people (a density of 60-64 people/km^2) (Lo Cascio and Malanima 2005: 203).

Whilst a range of models are produced in this thesis which may be used to support either argument, such ranges may be narrowed based on the situations investigated. This could result in three alternative scenarios: firstly either the low or high count is supported by the models; secondly a compromise model is achieved; or finally, the results could show higher supported densities than previously postulated.

1.2 The Study Area and methodology

The area assessed in this thesis lies immediately to the north of Rome and covers approximately 2,600km^2. It comprises the geomorphologically and culturally different regions of South Etruria and Sabina, situated on opposing sides of the River Tiber (Figure 1.1).

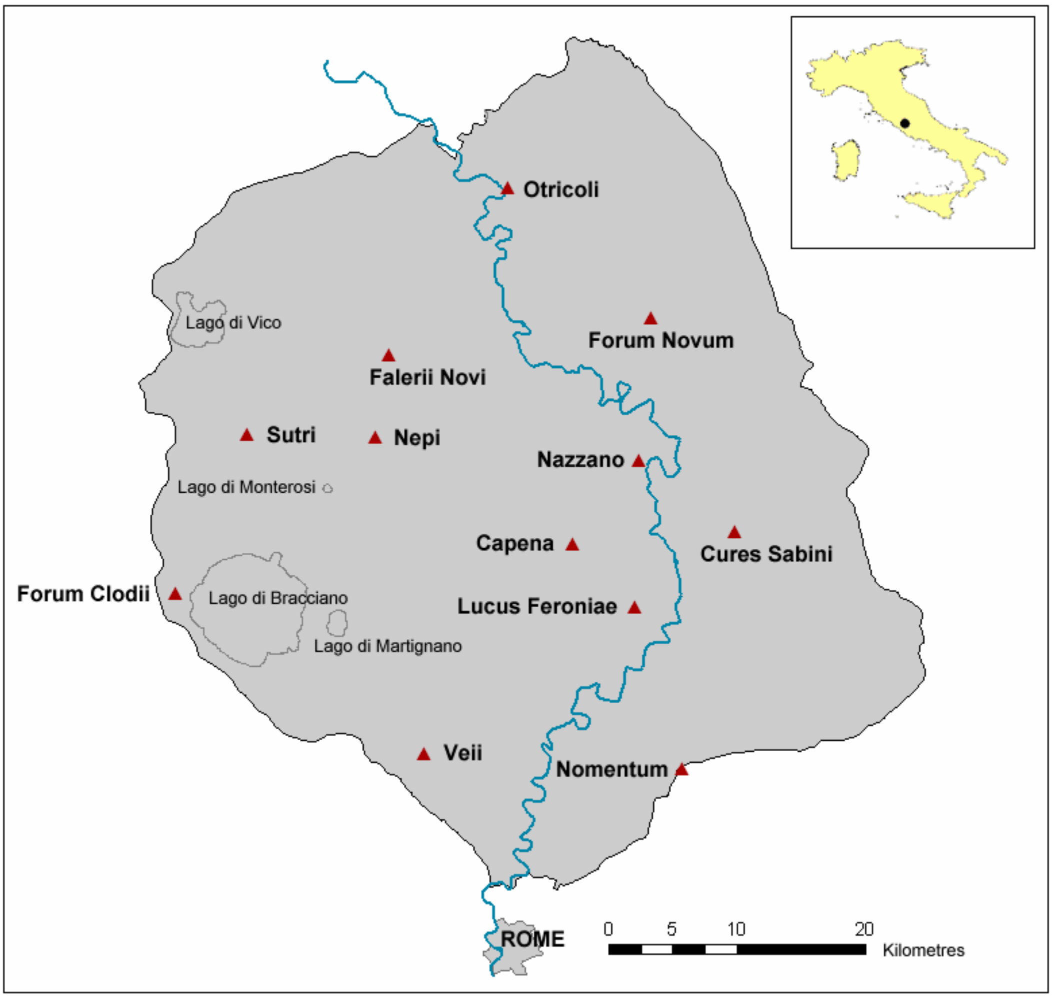


Figure 1.1 Map of the study area showing major towns, lakes and the course of the Tiber (base data from the British School at Rome)

The region of South Etruria was home to the Etruscan civilisation immediately prior to the Roman conquest (Barker and Rasmussen 1998; Haynes 2000), and the early importance of this area has been attributed to its fertility and the availability of mineral ores (Potter 1979:

20). On the opposite bank the Sabine people occupied land of varying topography. The area of the pre-Apennines was less conducive to traditional forms of arable cultivation due to its more severe topography and poorer soil fertility, whilst areas nearer the Tiber and further south towards Rome had underlying geology more suitable for arable agriculture and less severe relief (see Figures 1.5-1.7, pages 14-17). The Sabine region had an important role in the early history of the development of Rome (see Forsythe 2005) but never reached the height of civilization achieved by the Etruscans.

This research is based primarily on data collected from the South Etruria field survey, carried out during the 1950s-60s by John Ward-Perkins (see Potter 1979) and recently restudied by a number of academics collaborating on the Tiber Valley Project (H. Patterson 2004). It concentrates on the period from the 1st century BC to the end of the 1st century AD (the Late Republican to Early Imperial period), with an emphasis on the latter (this later period corresponding to the maximum density of sites in the study area). This presents an opportunity to examine a period in which land exploitation was at its most intensive, a situation not again matched in the area until the agricultural intensification of the early 20th century (Potter 1979: 13, 120).

Data regarding ancient farming practice were derived from ancient textual sources and modelled within a Geographic Information System (GIS) alongside a variety of geographic data from the region. This enabled existing theoretical models of location to be tested, as well as assessing the utility of using ancient textual data for quantitative modelling. Whilst it is probable that we cannot trust the sources for reconstructing a 'true' picture of productive landscapes, we can investigate the range of production statistics provided by them and model the demographic implications.

For this thesis, two different GIS packages are used. These are Idrisi (Clarklabs) and ArcGIS (ESRI). Idrisi is a raster-based GIS system that is particularly useful for dealing with problems such as decision-making (Chapters 4-5). To briefly explain, raster data is usually grid data such as images, geophysical data or continuous surface data such as digital elevation models. A raster file consists of x, y and z data. X and y are the two-dimensional location of the cell, and z is a value such as elevation, or categorical data such as soil type (Figure 1.2a).

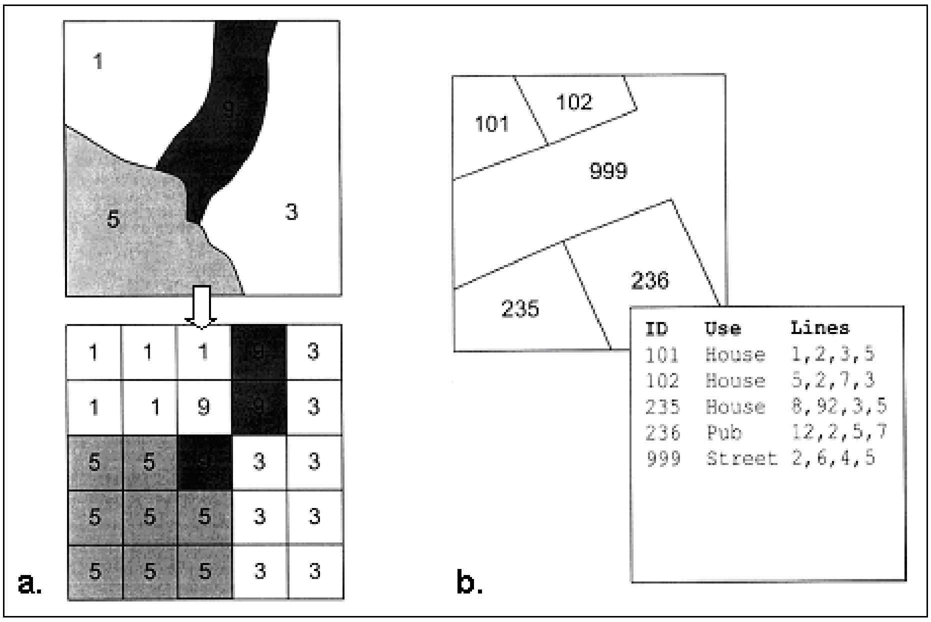


Figure 1.2 Raster (a) and Vector (b) representations of an area map (after Wheatley and Gillings 2002: 33, fig. 2.6)

Most of the other statistical and locational analysis was done within ArcGIS due to its superior handling of vector data and its advanced statistical modules. Vector data exists as x and y co-ordinate pairs, representing points, lines or polygons, with an associated attribute table (Figure 1.2b). This means that one point may have more than one value stored in the table, as opposed to raster data that is generally limited to one value only. For example, a road map may have a number of associated attributes such as time period, status of road (e.g. consular), whether paved or unpaved, and so forth. Both systems can analyse raster and vector data types, though each has its own advantages and disadvantages for certain processes.

Alongside the South Etruria database of over 3,000 archaeological sites, a number of digital maps have been created and compiled for the Tiber Valley Project. These, along with other resource data used within the study, are detailed in Table 1.1 below. The data supplied from the project were a mixture of raster and vector data.

Table 1.1 Resource data used within the study

Data description	Data type	Source
Late Republican and Early Imperial sites from the South Etruria Database	Database, and vector point file	British School at Rome
Digital Elevation Model (DEM), with 30m resolution	Raster grid file	British School at Rome/Regione Lazio
Modern land use 1:50,000	Vector polygon file	British School at Rome/Regione Lazio
Solid and drift geology 1:50,000	Vector polygon file	British School at Rome/Regione Lazio
River systems	Vector line file	British School at Rome/Regione Lazio
Roman roads	Vector line file	British School at Rome
Soil map 1:1,000,000	Raster grid file	The Commission of the European Communities (1985)
Cadastral maps 1835	Scanned images	Archivio di Stato di Roma (2002)
Late 19th and early 20th century climatic and production statistics	Text	Naval Intelligence Division Geographic Handbooks on Italy (1945, 3 vols.)

The data discussed thus far will be used to carry out an assessment of the region, the methodology (illustrated in Figure 1.3) is as follows: Chapter 2 begins by introducing issues in the study of Roman agriculture, and the nature of the evidence available. Chapter 3 assesses the potential size of Roman agricultural units, looking at both the ancient evidence for the whole of Italy, as well as an analysis of the sites from the South Etruria dataset itself. The sizes of certain sites are known from contemporary literary references and archaeological data (e.g. centuriation visible from aerial photography, field survey, excavation data and epigraphy). This evidence is examined in detail to establish whether regional patterns emerge, if certain unit sizes are more common than others, and whether such sources are credible for use in this type of study. The analysis provides model farm and estate sizes from which likely production figures and supported populations can be calculated.

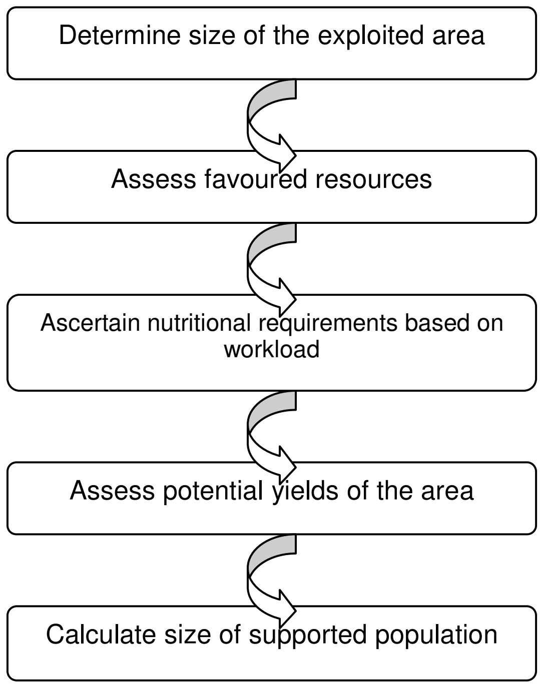


Figure 1.3 Methodology of this study

In Chapters 4 and 5 the available resources of the region are analysed. Locational analyses are carried out to investigate whether certain resources were favoured in locating rural sites, with two approaches used: firstly the known sites from the South Etruria database are assessed alongside available geographical data to see if any patterns emerge from their location; secondly the criteria for ideal farm location, as suggested by ancient sources, are input into a 'multi-criteria analysis'. The known sites from the database are then compared to the resulting map, showing areas that conform to the Roman idea of good (or bad) farm location. It is then possible to see if the known sites used similar criteria for farm location as those suggested in the ancient texts.

Following this, crop yields, methods of agricultural practice (e.g. fallowing), and the potential contribution of livestock are evaluated in Chapter 6. Production figures from both ancient and modern sources in Italy are investigated in order to gain insights into potential yields for the study area. From this it is possible to determine a carrying capacity (or, more accurately, a range of capacities) for the study area, whilst a study of workload and nutrition in Chapter 7 enables the food requirements of an agricultural worker to be estimated. Data from ancient sources regarding how much work a Roman farmer was likely to have carried out annually is used in conjunction with skeletal data and official publications on nutritional requirements. This provides a range of calorific values from which the population capable of being supported by local production can be determined.

The next stage is to apply these data to the study area. In Chapter 8, yields for the area are modelled based on the assembled data. This provides a total output for the region and the number of people capable of being supported. The demographic implications of the range of yields produced are then compared to previous population figures suggested for the area. Alternative yield figures are also tested and, as field survey does not recover 100% of sites, hypothetical production figures are tested using a set of sample sites.

The eventual aim of this study is to test the demographic implications of statements in the ancient sources regarding yield and agricultural practice through modelling within GIS. All of these results are used to investigate potential rural and urban populations. The production models are broadened to investigate how the towns in the area were likely to have been supported. A study of possible surplus from the production figures goes some way to inform us of how likely local centres were to have been reliant on their hinterlands or on imports from outside the Middle Tiber Valley for their food supply.

The data modelled in this thesis forms part of a project with access to a unique dataset covering a large region containing thousands of archaeological sites. However, this methodology is also intended to be applicable to other regions and time periods, which may not have access to the same type of data or cover as wide an area. Indeed, the basic approach outlined in Figure 1.3 has already been used in a Romano-British context, where the urban dependency of Wroxeter Roman city on its hinterland was modelled using similar data. This included basic geographical data such as that used here alongside site location data recovered from both field survey and aerial reconnaissance (White, Gaffney and Goodchild 2007).

Though a huge number of GIS files were created during this study (see Appendix VII), these are, however, predominantly files that have been created during the modelling process from the original data sources listed in Table 1.1 (page 7). These, as seen, consist purely of basic geographical data plus the site database, demonstrating that in fact only a relatively small amount of initial data is required to begin such a model. Basic geographical data regarding the topography and either underlying geology, soils or land use is the minimum needed, which may be supplemented by other geographical data (e.g. rivers and roads), whilst aspects such as site location may be randomly generated if lacking known sites in the area, or recovered through other means such as the Wroxeter example above. Additionally, whilst this study has been fortunate to have comprehensive ancient texts and a huge archaeological database to draw on, these factors may be replaced with anthropological parallels in an area where such data are lacking.

Though it is not possible to simply lift the models and use ‘as is’ in a different region, the overall structure of study will be pertinent in many areas. Figure 1.4 therefore shows the modelling process in more detail, highlighting the questions being asked at each stage and where alternative sources of data may be used. Whilst the processes may appear complex at first glance, the different coloured backgrounds highlight areas which roughly equate to the actions carried out in each chapter: the green section at the top left refers to Chapter 3, where site size is examined and exploited territories created; the purple section is the locational analysis and multi criteria analysis of Chapters 4 and 5; the blue section is Chapter 6 where yield maps are created; the pink section is the analysis of workload and nutritional requirements in Chapter 7; and finally the yellow and lilac sections refer to the agricultural model for total production followed by the investigations into surplus production in Chapter 8.

By dividing the model in this way it is clear which data are necessary for each component and which may be substituted for alternative data sources; for example crop yields may be modelled based on ancient data, or may be gleaned from more recent historical yields or even modern land use if ancient data are not available; desirable areas may be based on Roman perceptions of suitability, or they may be inferred from the best conditions for modern crops.

Such a model is, of course, only as good as the data on which it relies, and so clearly the more information one has regarding agricultural practice and the geography of the area, the more confidence may be placed in the model produced.

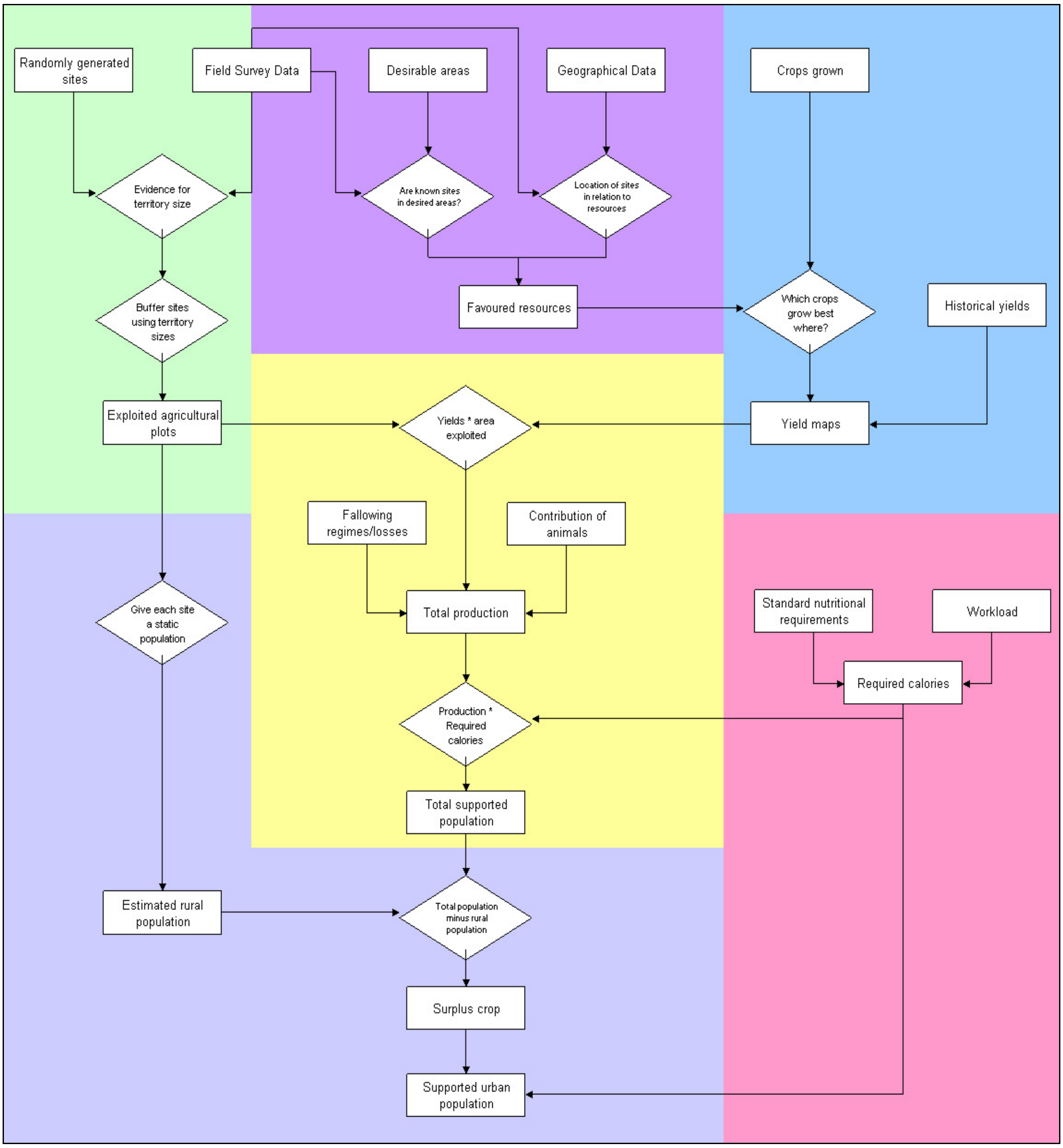


Figure 1.4 Flowchart showing the processes for modelling agricultural productivity and supported population

1.3 The Geography of the Middle Tiber Valley

1.3.1 Topography

The study area covers two geographically diverse regions – South Etruria and Sabina Tiberina, on opposing sides of the river Tiber. Examining the digital dataset for the topography of the study area, the region consists mostly of low-lying hills. The more mountainous areas are peripheral to the study area, with the more extreme slopes more distant from the river valley towards the Apennines in the east. The highest altitude reached is 1,269 metres above sea level, although the mean height is 139 metres, indicating that much of the land in the study area is low-lying.

Comparing the two areas of South Etruria and Sabina visually (Figure 1.5) we can see that the Sabine area is more mountainous, whilst South Etruria maintains a more even altitude and slope throughout, although does have areas of more extreme relief such as the volcanic craters and the mountain of Monte Soratte (see also Figure 1.7, page 17). The Tiber Valley itself is flat-bottomed due to the large-scale alluviation that has occurred here both in prehistoric and historic times. This is also the case for the smaller streams in the areas which have low relief alluvial deposits, incised by river trenches of between three and eight metres in depth (Judson 1963: 898).

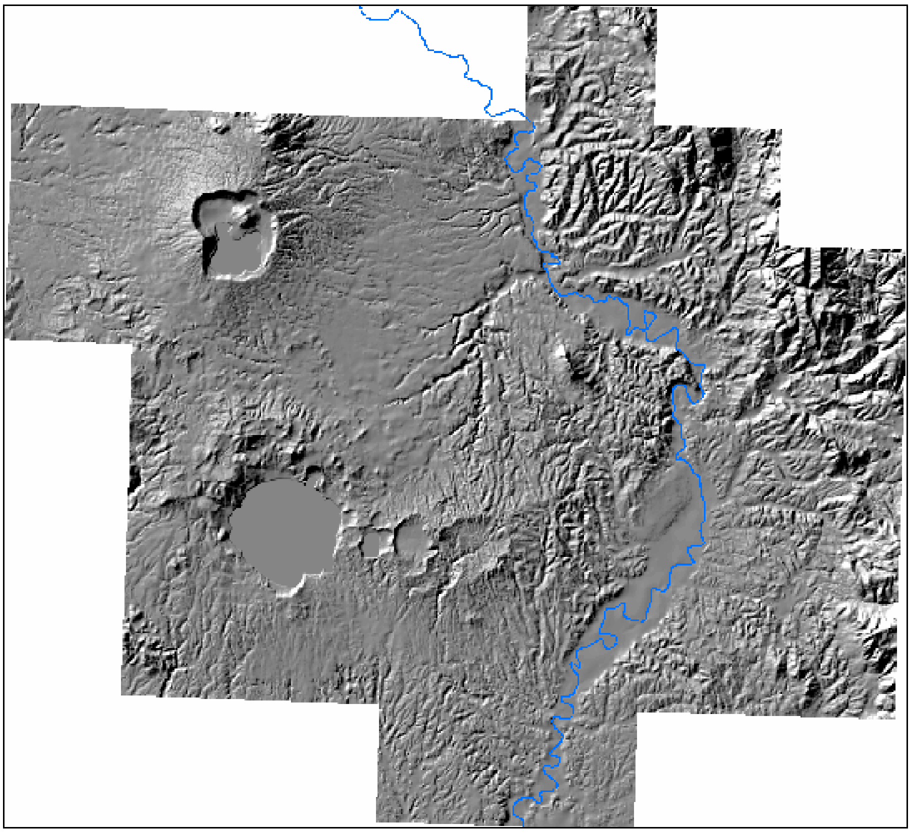


Figure 1.5 Hillshaded DEM of the study area, showing the river Tiber overlaid (British School at Rome)

1.3.2 Soils and geology

Soils are problematic within this area, as the region lacks a definitive soil map. The only available source is the 1:1,000,000 soil map of Europe (The Commission of the European Communities 1985). This is an inadequate scale for detailed analysis, although does provide a basic guide to the nature of soils in this area (Table 1.2 and Figure 1.6). Any assessment of soils for this study, however, is a difficult matter. The character of modern soils, such as their fertility, is unlikely to reflect the situation in the Roman period, as the climate has changed and soil has been lost to erosion and other factors (Shiel 1999: 67).

Table 1.2 Soils in the study area (The Commission of the European Communities 1985)

Soil Type	Area In Hectares	Area in %
Ranker	101,340	39.39
Calcic Cambisol	52,840	20.54
Dystric Cambisol	33,491	13.02
Orthic Rendzina	24,060	9.35
Dystric Fluvisol	20,105	7.81
Gleyic Cambisol	12,947	5.03
Calcaro-Vertic Cambisol	11,621	4.52
(Dystric) Podzoluvisol	693	0.30
Eutric Fluvisol	184	0.07

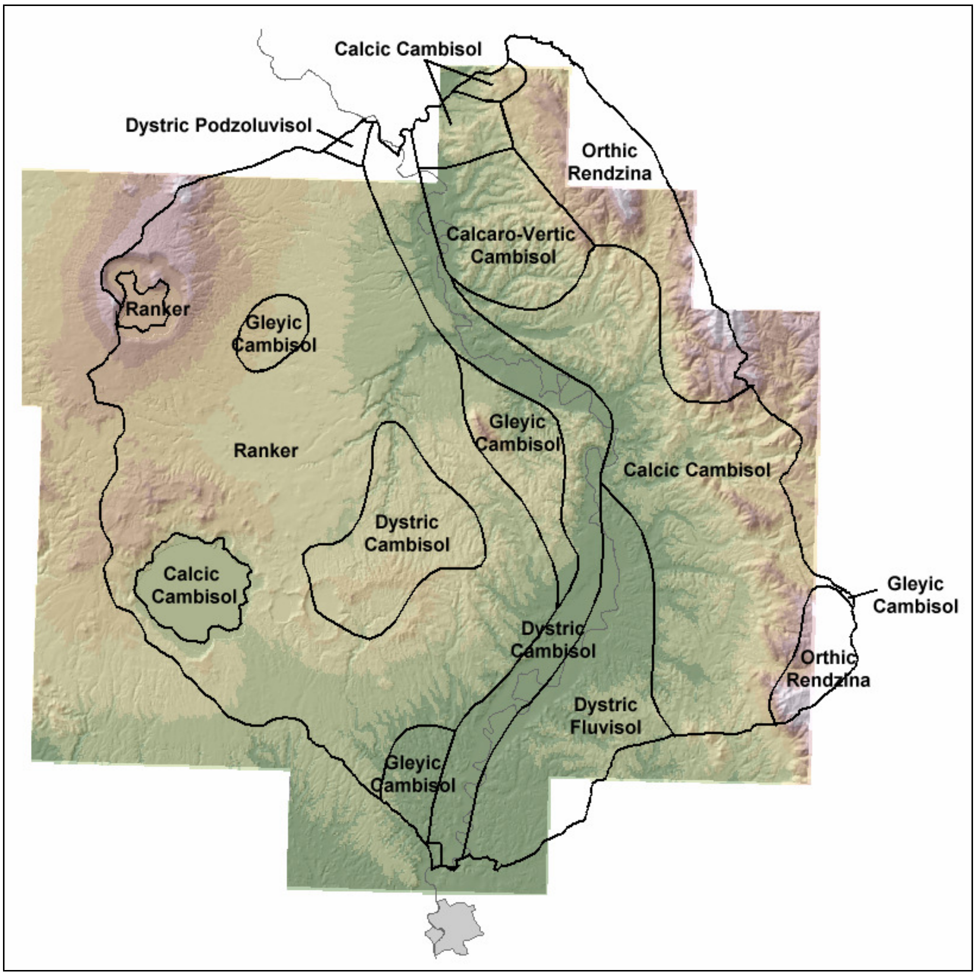


Figure 1.6 Soil map of the study area (The Commission of the European Communities 1985) overlaying topography (British School at Rome)

General soil types tend to have uniform characteristics. In the case of the cambisols, these develop particularly in mountain regions due to erosion and deposition processes. These soils tend to be medium-textured with good structural stability and high porosity. They hold water well and have good internal drainage. Generally, cambisols are thought to make good agricultural land, with dystric cambisols used for mixed farming and grazing. Vertic and calcaric cambisols, if irrigated, are good for food and oil crops (Driessen and Deckers 2001: section 5).

Fluvisol development is conditioned by topography. They have good natural fertility and tend to be used for annual crops, orchards and grazing, although some measure of flood control or irrigation is often required. The soil that covers the largest area, however, is a ranker, which is generally believed to be less fertile and poor for agriculture. These soils are either shallow soils over acidic rock, or deeper soils with a high gravel content (Driessen and Deckers 2001: section 4). Other soils present include Podzoluvisols, which contain clay and can form in fluvial deposits in flat areas. These soils are not suitable for cultivation due to poor fertility and drainage problems (Driessen and Deckers 2001: section 9). Orthic Rendzinas are a shallow soil formed over limestone considered unattractive for arable cultivation, but with some potential for tree crops or grazing (Driessen and Deckers 2001: section 4).

The river Tiber, as well as bisecting the study area, also divides the region into two main solid geological formations. In South Etruria, to the west of the river, the area is mostly made up of volcanic deposits with two principal volcanoes. These are Vico (Monti Cimini) and Bracciano (Monti Sabatini), the latter being part of the larger Sabatini Volcanic complex. These are illustrated on the topographic map (Figure 1.7). Vico is the crater to the north-west, with the lake just visible inside. The shallower crater of Bracciano lies at the lower right of the image, and is occupied entirely by the lake. Other craters from the Sabatini complex can also be seen, including the crater lake of Martignano and the drained basin of Baccano, lying directly to the east of Bracciano, along with the Sacrofano crater further east. The Cese centre is not visible on this map.

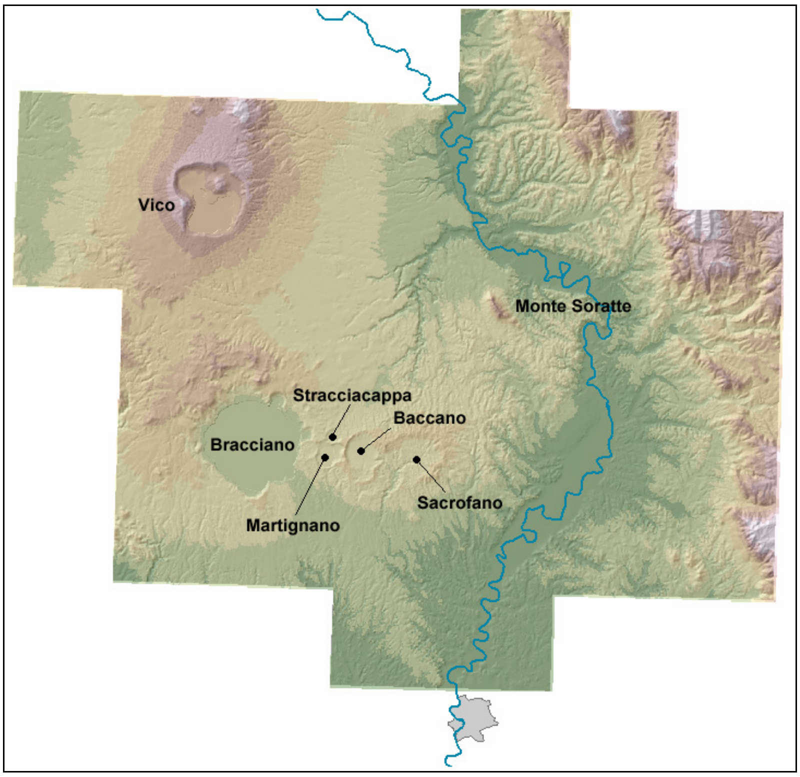


Figure 1.7 Topographic map showing the location of volcanic basins and Monte Soratte (British School at Rome)

The deposits associated with these volcanoes rise gradually eastwards from the coastal lowlands towards the Tiber, creating a plateau consisting predominantly of basaltic and trachytic tuff of Pliocene age. The plateau itself is dated to the Quaternary period and has an undulating surface, punctuated by the two volcanic cones, now occupied by lakes. The surrounding countryside is incised by deep valleys, forming the drainage pattern seen clearly on Figure 1.5 (Naval Intelligence Division 1945a: 277; Walker 1967: 76, 171-172).

Towards the Tiber, the plateau falls sharply to the east, cut by the river valley. In places the river has eroded the volcanic tuff to reveal underlying Tertiary deposits (Naval Intelligence Division 1945a: 278-9; Walker 1967: 174). This valley area also contains the most recent deposits – alluvium dating from the Pleistocene and Holocene. As shown in the geological map (Figure 1.8), these alluvial deposits fan out along the tributary river system.

The second major geology type is confined mainly to the west of the River in the Sabine region, with some encroachment into South Etruria. The dominant deposits here are sands and conglomerates of the Tertiary period, with some areas of clay. These sediments overlie the limestone terrain of the pre-Apennines that begin to appear at the eastern edge of the study area. Limestone is rare across the river in South Etruria, the only major outcrop being the dominant mountain, Monte Soratte, in the centre of the study area (Walker 1967: 79, 174).

The geological composition of the two regions is detailed in Table 1.3. Only those lithologies covering more than 1% of the area are listed.

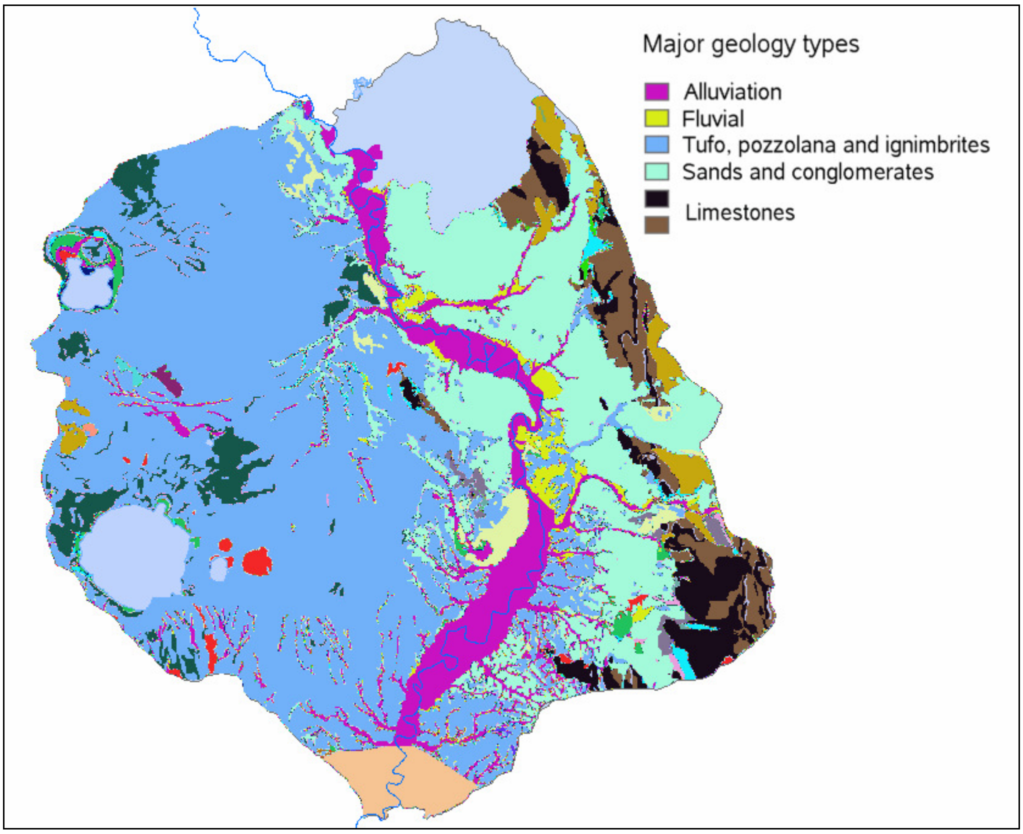


Figure 1.8 Major geology types of the study area (British School at Rome)

Table 1.3 Comparison of geology types in the two regions

South Etruria		Sabina	
Geology	% of area	Geology	% of area
Tuffs, pozzolana, ignimbrites	67.38	Sands, sometimes with concretions	39.85
Quaternary and recent alluviation	8.08	Quaternary and recent alluviation	12.96
Sands, sometimes with concretions	6.66	Tuffs, pozzolana, ignimbrites	11.08
Lava flows	5.77	Volcanic debris, melted or weakly	9.70
Travertine	1.69	Micrite, compact with basalt, marly limestone and marl	9.64
		Marl with limestone intercalations	4.26
		Other fluvial deposits	3.86

1.3.3 Vegetation and land use

Even today, urban or industrial areas only constitute approximately 5% of the total study area, meaning that the vast majority of the land still has an agricultural, pastoral or forest economy.

Etruria has been renowned for cereal cultivation since the Roman period (e.g. Columella *Rust* 2.6.3, Pliny *NH* 18.66, 18.86-87, and Pliny *Ep*. 5.6.10-12), just as the Sabine region was known for oleoculture (Columella *Rust*. 5.8.5). Today, this is still the case, as can be seen in the 1:50,000 modern land use map (Figure 1.9) and in Table 1.4.

Table 1.4 Comparison of land use in the two regions of the study area

Whole study area		South Etruria		Sabina	
Land use	% of area	Land use	% of area	Land use	% of area
Arable	32.85	Arable	37.94	Complex	25.13
Complex	23.11	Complex	21.96	Arable	23.94
Woodland	14.86	Woodland	13.52	Olives	23.12
Olives	10.99	Orchards	10.34	Woodland	17.22
Orchards	7.40	Water	5.15	Urban/industrial	4.47
Urban/Industrial	4.61	Urban/industrial	4.69	Orchards	2.24
Water	3.49	Olives	4.06	Scrub	1.85
Scrub	1.55	Scrub	1.61	Meadow/Pasture	0.65
Meadow/Pasture	0.40	Meadow/Pasture	0.26	Water	0.59
Burnt areas	0.27	Burnt areas	0.21	Burnt areas	0.36
Meadow	0.12	Meadow	0.14	Bare rock	0.20
Vineyards	0.11	Vineyards	0.08	Vineyards	0.15
Bare rock	0.07	Marsh	0.05	Meadow	0.08
Marsh	0.04			Marsh	0.01

Arable is concentrated in the central region of the study area (Figure 1.9), mostly in Etruria, but extending across the Tiber floodplain into parts of Sabina. This area has the flattest terrain and a concentration of volcanic rocks. The arable is interspersed with areas of 'complex agriculture'. This term includes various combinations of intercropping using cereals, olives, vines, or other tree-crops and vegetables, a regime that is particularly common near urban centres and often occurs in the Sabine region. This is not immediately obvious from the modern land use map, but was determined from the historical cadastral maps from the area (see Chapter 4).

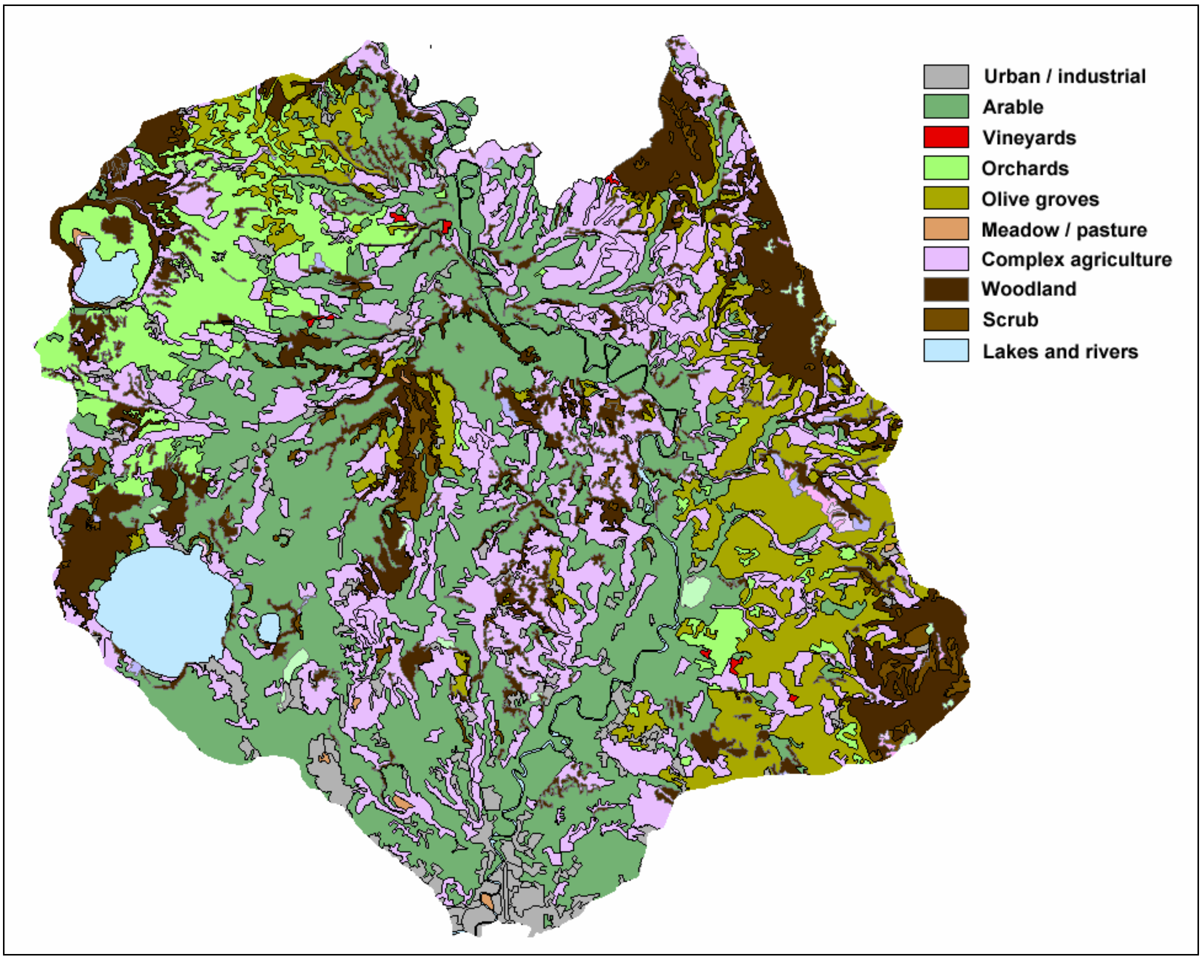


Figure 1.9 Land use in the study area (British School at Rome / Regione Lazio)

Olives are mostly cultivated in the Sabine region, to the east of the study area, and to a much smaller degree in the upper regions of South Etruria (see Figure 1.9). Given the hilly nature of the terrain in the Sabine region, it is unsurprising that this type of agriculture is the most prominent. This is probably due to the ease with which these trees grow on steeper slopes and thinner soils, as discussed in Chapter 6. Dedicated vineyards are scarce, occurring only in very few areas, and are likely to be more prevalent in combination with other crops.

Woodland and forest are likely to be less prolific now than in previous years. Much of it is thought to have degenerated, being replaced largely by scrub and coppice, mainly due to the extensive use of the forests for fuel, or clearing for agricultural use and the building of urban centres (Walker 1967: 172; Naval Intelligence Division 1945a: 269; and see Chapter 4).

1.3.4 The River System

The geography of the study area is dominated by the presence of the river Tiber. This river bisects the study area, separating the pre-Apennine mountains and the Sabine region from the volcanic areas of South Etruria. It is the largest river of peninsular Italy and it is of obvious historical importance to settlement in this area. The Tiber is 250 miles long and has a catchment basin of 6,645 square miles. This huge catchment basin means that the study area is well drained into the Tiber, and consequently the region was not of a swampy nature, therefore escaping the unhealthiness associated with such places (for example the Pontine marshes). The volume and speed of the river are highly variable as there is a marked seasonal variation. There is also a tendency for the lower part of the Tiber to flood (Naval Intelligence Division 1945a: 45-46, 285; Walker 1967: 154).

The river Tiber and its tributaries tend to have high water in March and April, followed by low water in July-September, and a second minor flood in November, corresponding closely with the rainfall regime. This has important implications for their navigability – the same pattern is suggested by Pliny the Younger in the Roman period, when he states that the river is only navigable in the high waters of spring and winter (*Ep*. 5.6.12). The Tiber connects a number of lake basins, the main ones in the area being Lago di Bracciano, Lago di Martignano, and Lago di Vico, all on the west side of the Tiber (Naval Intelligence Division 1945a: 51). Lago di Vico lies in the volcanic crater of the Monti Cimini and has no surface outlet. Lago di Bracciano, a crater lake within the Monti Sabatini, has an artificial outlet to the Tiber constructed in the Roman period in order to supplement the flow of the river (Naval Intelligence Division 1945a: 278).

1.4 Conclusions

In this chapter the data and methodology used within this study have been outlined as an introduction. The following chapters will work through the methodology systematically, resulting in a model of agricultural production and the subsequent supported population that will add to the current debate on Roman economy and demography, and could be applicable in other time periods or parts of the empire. Again I must stress that the results produced are models and do not claim to be reality. However, the figures put forward in later chapters are not outside the realms of agricultural possibility and it is thought that some models may reflect the productive and demographic situation within a fair margin of error, consequently providing important insights into the inner workings of the economic base of the hinterland of Rome.

2 ROMAN AGRICULTURE AND RURAL SETTLEMENT

2.1 Issues in the study of Roman agriculture

The organisation of land is of particular importance to this study as productive potential varies with the size of the farm or estate due to the differing farming systems employed. In order to gauge potential production levels, it is therefore necessary to first determine the state of agriculture during the period in question and to investigate the context within which production was taking place. In the Late Republican and Early Imperial period Roman Italy was predominantly agricultural. Between 80-90% of the population was likely to have been engaged in agricultural activities, possibly decreasing to around 70% in the Late Imperial period (Hopkins 1978: 6; Evans 1981: 428). Agricultural production was consequently of the utmost importance to the development of urban populations, yet rural settlement has received comparatively less scholarly attention than ancient cities and towns (Horden and Purcell 2000: 90-92).

A brief outline of the historical background to agrarian issues in the Late Republic and Early Empire is carried out here in order to establish the likely issues that may have affected patterns of landholding and exploitation. The types of evidence available, both textual and archaeological, are then discussed in Section 2.2 regarding their benefits and drawbacks to such a study. These data will be used in later chapters to establish factors such as farm size, possible practice, and production levels.

2.1.1 The historical background: from the Gracchi to the 1st century 'crisis'

Scholars of Roman economic and social history have used two periods in particular to characterise the state of Roman agriculture and rural settlement – the Gracchan period *c*.133-122 BC, and the 1st century AD. These two periods lie immediately before and towards the end of my period of study, and as such give context to the agrarian situation in the Late Republic and Early Imperial period.

Modern debates on the Roman countryside in the Gracchan period are intrinsically linked to discussions of manpower and warfare, as free peasants formed the majority of conscripts in a time characterised by war, upheaval and Roman expansion (De Neeve 1984: 8). It has been postulated that a combination of aristocratic land hunger and the extended absence of peasant-soldiers from their land during the Punic Wars contributed to a decline of the free peasantry and their replacement by slaves. The heavy military losses of the period meant a severe reduction in the rural community, with those returning finding their farms neglected and war-torn, and often reduced to debt. This is thought to have precipitated a change in the system of land organisation into larger units capable of producing a surplus using less labour (Hopkins 1978: 2-3). This larger-scale method of production also meant that small farmers were increasingly unable to compete in the marketplace (De Neeve 1984: 9-10).

Studies of this period (e.g. Toynbee 1965; Frank 1933: 232-240; Brunt 1971a: 55) have tended to base such analyses on two ancient accounts (Plutarch *Ti. Gracch*. 8-9 and Appian *B Civ* 1.7-11). Plutarch, in his *Life of Tiberius Gracchus*, referred to the decline of peasant farmers due to the flouting of the *Lex Licinia* – a law that aimed to prevent landowners from amassing large tracts of public land. According to Plutarch, Tiberius Gracchus observed whilst travelling through Etruria that,

> *…the country had been deserted by its native inhabitants, and how those who tilled the soil or tended the flocks were barbarian slaves introduced from abroad.*
>
> Plutarch *Ti. Gracch.* 8.7

The passage by Appian (*B Civ.* 1.7-11), describes how the early large landowners acquired a large portion of the undistributed lands via purchase or often by force, despite legislation to the contrary, and farmed them using slaves. Italian smallholders are consequently thought to have diminished in number whilst the number of slaves working large estates (known as *latifundia*) increased.

The most famous passage concerning the *latifundia* is that by the Elder Pliny, written in the 1st century AD.

> *In old times it was thought that to observe moderation in the size of a farm was of primary importance … And if the truth be confessed, large estates have been the ruin of Italy, and are now proving the ruin of the provinces too.*
>
> *NH 18.7.35*

This passage has been taken by scholars (e.g. Rostovtzeff 1957: 198) to indicate the disappearance of small- and medium-sized establishments, and linked to economic decline. However, it has been argued that this statement was more likely to have been a consequence of Pliny's own dislike of slave-staffed estates and not necessarily a direct comment on the increase of large-scale units (Duncan-Jones 1982: 323-4)

The view offered by Pliny, Plutarch and Appian is indirectly supported by the writings of the Roman agronomists, particularly Cato the Elder, whose agricultural handbook described the management of estate-style agriculture and husbandry, rather than the subsistence regime of a 'peasant' farmer. However, this can be argued against for a number of reasons. Firstly there is no reason why more than one system of land exploitation could not have co-existed, and secondly it is a text that is firmly rooted in the rhetorical tradition of the mid-2nd century BC (see Section 2.2).

The alleged decline in the rural population has been challenged by a number of scholars. Indeed the theory was challenged early on by K.D. White who highlighted a misuse of the term *latifundia*, and demonstrated a great variety in the size of plots and pattern of land use across the country. The word *latifundia* was never used by the agronomists and is actually limited to a narrow post-Augustan period, but has nevertheless been used as a catch-all description of large estates practicing monoculture (White 1967: 62-65, 73). Dyson (1992: 33) supported this argument by highlighting the fact that the term *latifundia* itself was,

> *…a vague and ideologically charged one even for the Romans…* [representing] *a process of economic and social corruption…*[and their spread] *was associated with greed and luxuria.*

True *latifundia* are now thought to have only existed for a brief period, and located in only a small area of Italy.

Dyson also argued for a quick recovery from the Punic wars: new colonies were established at this time (requiring large-scale mobilisation of manpower), and it is likely that the population recovered within a generation or so (1992: 28). Rosenstein (2004) follows this by arguing that military service would have had less of an impact than originally thought, with families recovering from the Punic Wars rapidly due to the existence of sons too young for service. He also suggests that the evidence for a massive influx of slaves to staff the great estates is weak, and that any new slaves served to replenish losses made during the war rather than increase numbers dramatically (Rosenstein 2004: 9-10).

Aside from historiographical issues, the biggest contribution to dispelling this traditional view has come from archaeological data. In particular, the proliferation of field survey in Italy over the last fifty years has contributed to the realisation that the rural landscapes of Roman Italy were in fact incredibly diverse, a subject which is discussed in greater detail in Section 2.2 and Chapter 3.

Moving on to the later period, the 'crisis' of the late 1st century AD is thought to have been the end result of a long process, beginning with the alleged problems dating from the Gracchan period. A decline in agricultural production is believed (e.g. by Rostovtzeff 1957) to have occurred during the 1st century AD, based on a number of factors. The emperor Domitian's Vine Edict of AD 92 ordered the destruction of many vineyards in the provinces, and forbade the establishment of any new vineyards in Italy (Suet. *Domitian* 7.2; Statius *Silv*. 4.3.11-12). This has been taken to imply an overproduction of wine alongside a shortfall in cereal production (as discussed by Morley 1996: 135-6), and has been cited alongside evidence from the Trajanic *Alimenta* inscriptions (see Chapter 3.1.4) that are thought to imply that landlords were in need of capital. Additionally, comments made by other ancient authors regarding the state of agriculture have been used to support this theory of decline. Columella, for example, in the opening passages of his 1st century work on agriculture spoke about:

> *…the shameful unanimity with which rural discipline has been abandoned and passed out of use.*

His aim was to highlight the profitability of certain forms of agriculture in order to encourage the elite back to farming. Pliny the Younger (*Ep*. 9.37) also laments the state of agriculture on his estates.

> *During the past five years, despite the large reductions I made in the rents, the arrears have increased and as a result most of my tenants have lost interest in reducing their debt because they have no hope of being able to pay off the whole; they even seize and consume the produce of the land in the belief that they will gain nothing themselves by conserving it.*

Traditionally the 'crisis' has been blamed on the economic emancipation of the provinces, causing a drop in the market for Italian-grown produce such as wine and oil. The new provincial imports to Rome, as well as inherent problems within the organisation of slave labour caused a decay in the industry and commerce of Italy (Rostovtzeff 1957: 192-201; in Patterson 1987: 115). Much of the evidence used to support this idea of crisis has been examined by Patterson (1987). He argued against the vine-edict as a failed legislation and being unrepresentative of Italian production, and against other textual evidence such as the letters of Pliny the Younger as being the product of local problems rather than a wide-spread issue (1987: 118, 120). The existence of the alimentary schemes are argued as demonstrating the presence of rural poverty in certain areas (including parts of South Etruria) rather than an impoverished elite and a general productive crisis (1987: 124-133).

One study has explored this 'crisis' with evidence from regional field surveys (Ikeguchi 1999/2000). Investigation, however, showed that there was much regional variation (cf. Patterson), and that an overall pattern could not be determined for the whole of Italy. Ikeguchi argued that a crisis in this period was likely to have affected mostly wine and oil producing villas and as such "*was not nonexistent, but was overcome*" by a series of regional responses. These included transition from slavery to tenant farmers, altering economy from arable to pasture or, in the case of South Etruria, exploiting the massive urban market at Rome (Ikeguchi 1999/2000: 36; see also Section 2.1.2).

Competition with cash crops such as wine and oil is unlikely to have adversely affected cereal production. It has been argued that cereal production remained stable whilst other crops increased, rather than replaced, the staple crop (Garnsey 1988: 191). An earlier study (Garnsey and Saller 1987: 59-61, 76) also alleged that the sources were insufficient evidence to support the idea of any kind of decline, and in fact described the idea of the collapse of the small farmer as "*a cliché of Roman agrarian history*". This has been investigated further by the recent calculations of Jongman (2003). He showed that, according to his model, the area needed to supply Italy with its wine requirements was in fact a minute percentage of the available agricultural land, implying that the idea of agricultural decline, based on assumptions from the textual and epigraphic evidence, was unfounded. He stated that, should the suggested change in agriculture from cereals to viticulture have occurred, "*it would have left Italy both fatally hungry, and dangerously drunk*" (Jongman 2003: 111).

Morley (1996: 10-11) has highlighted the modern preconception that Italian agriculture was prone to stagnation and crisis, compared to the more dynamic and prosperous provinces, and believed there to be little evidence to support the idea of widespread rather than regional problems. It had been earlier argued that urban development on such a grand scale could not have occurred as it did during the early Imperial period if the underlying economic base was in crisis (Garnsey 1988: 191), an idea that I will return to in later chapters.

This section has outlined the major historical themes regarding agriculture and rural settlement likely to have affected the study area in the Late Republic and Early Imperial period. These are highly debated themes and, though not explicitly the focus of this study, play a role in the development of the area. Were the traditional views to be believed, then the process of agricultural decline and the disappearance of the small farmer would have been well under way in the period under study. This would no doubt have had a significant effect on the organisation and size of productive units, and consequently their output, as would any later agricultural crisis.

2.1.2 The potential impact of Rome

A number of theories regarding exploitation and cultivation practices have been put forward in recent years. The Middle Tiber Valley's relationship with Rome is central to this, yet its proximity to Rome and the potential economic implications of this were not emphasised by Potter in the original synthetic South Etruria survey publication (1979), and only a limited series of economic models have since been debated (Witcher in press). These include models based around concepts such as the consumer or producer city (e.g. Finley 1973; 1977), or geographical models of organisation such as von Thünen's *Isolated State* (von Thünen 1966, first published 1826) or Central Place Theory (Christaller 1966, first published 1933; Roberts 1996).

The theoretical framework of von Thünen was used by De Neeve in his study of location and economy (1984). Von Thünen's theory saw the division of a city's territory into concentric zones of production, each located according to its most economic use (e.g. regarding sale price against transport cost). Though an idealised model, it is still a useful way of analysing possible agricultural practice. The theorised zones were, from the market centre outwards, horticulture and other perishable goods, forest, three different arable systems, and then ranching (Figure 2.1).

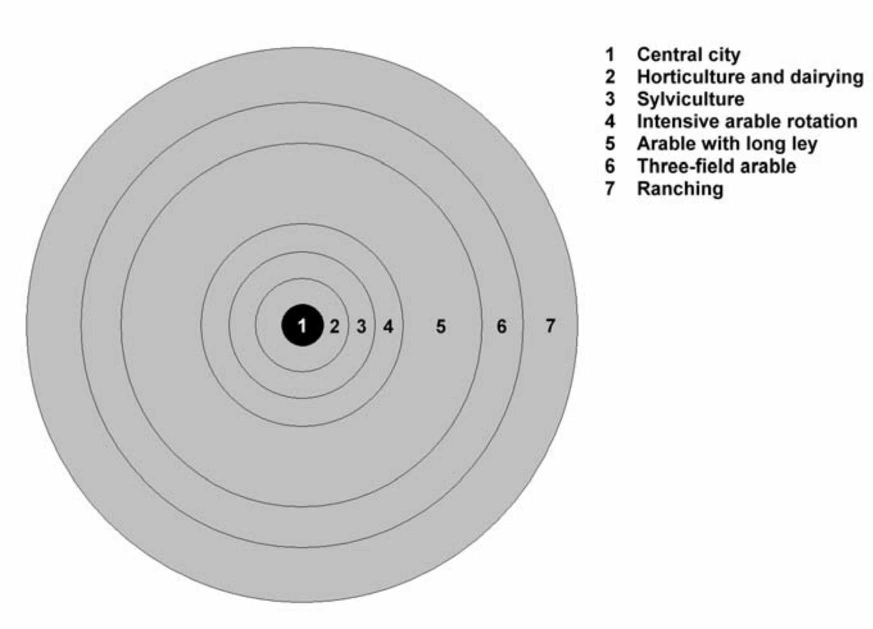


Figure 2.1 von Thünen's 'Isolated State' (after Roberts 1996: 27, fig. 4)

The effect of factors such as transport networks or the presence of secondary market centres may significantly distort this ideal model, and as such De Neeve argued that, rather than zones of products, we should look instead at zones of agrarian systems. Also factors such as farm size, labour, and population density should be taken into account (1984: 13).

Despite the problems, von Thünen's model was still held to have value. As Rome's productive hinterland could be argued to encompass much of the Mediterranean area, the model could therefore be enlarged to include a larger region. As such, the large-scale pastoralism could be argued to be occurring in the appropriate peripheral areas (e.g. Apulia and Lucania), and likewise intensive horticulture near Rome (1984: 16-17).

However, as emphasised by De Neeve (1984: 20), zones of production were not exclusively devoted to one form of economy. Though certain areas could be characterised as, for example stock-breeding areas, a number of alternative agrarian strategies would also have been present. For example, not all farmers would be producing for the market, and for many the main aim would have been subsistence rather than marketable surplus. Also, the existence of small towns as market centres would have created satellite areas of production (1984: 14-15, 22).

Morley (1996) also used the von Thünen model to investigate likely production in Rome's hinterland. He argued that agricultural strategies would have altered in response to demand from Rome and that, rather than the resource exploited (e.g. crops, animals, timber) changing with distance from the centre, instead the proportion cultivated for the market and the combination of crops grown would alter (Morley 1996: 108-111). Also the idea that perishable goods were located nearest the market is reflected in his theory regarding *pastiones villaticae* (market-oriented luxury produce, see Chapter 2.2.2 and 6.2.2) in the Roman *suburbium* (Morley 1996: 88-90). John Patterson (2004) supports this model to some extent in a recent investigation into the impact of Rome on the study area in terms of both settlement density and exploitation patterns. He argued that field survey results support this model, given the increasing settlement density nearer the capital. The role of the Tiber in transporting goods to market is also highlighted, regarding the extension of the exploitable area capable of supplying Rome.

It has been argued that the growing demands of the capital would have impacted heavily on the study area in this period. Morley's model suggests that rural sites would have altered their agricultural strategies in response to the changing market, altering cultivation techniques such as crops grown or amount of fallow, as well as the organisation of labour in order to intensify production for maximum returns (Morley 1996: 142). However, as pointed out by Patterson (2004: 65), this would only have been possible for those who could afford it. Whilst the rich could invest in new forms of production to satisfy Rome's demands, what would have happened to the remainder of the rural population? Smaller units, more geared towards self-sufficiency with limited marketable surplus would not necessarily have followed such strategies, and it is to this variety of settlement types (not just villas) we must look to attempt an agricultural model of the region.

The geographical approach of von Thünen is criticised by Horden and Purcell (2000). The idea of cities dependent on constrained 'natural' hinterlands is condemned, and instead it is suggested that such concepts are unhelpful when dealing with the Mediterranean. Due to redistribution of the 'normal' Mediterranean surplus (see for example Halstead 1989), a city's economic hinterland is impossible to define, and is instead changeable and fragmented, being at its most extensive during times of shortage drawing on a larger resource-base (Horden and Purcell 2000: 112-113). This concept of 'dispersed hinterlands' was applied to the study area by Witcher (in press), who argued that models such as von Thünen are inapplicable due to variations in resource quality and transport networks altering ease of production and access.

These different concepts impact on this study peripherally, but still have important consequences. As already stated, this thesis is only indirectly concerned with the provisioning of the capital and we must not let simple models of supply and demand for Rome obscure the smaller-scale workings of the whole region.

> *Taking a 'Rome-centric' perspective … changes our perception of the relationship from one of diversity to uniformity, from local detail to 'grand plan'*
>
> (Witcher in press)

Consequently, whilst the provisioning of the capital will receive some attention (Chapter 8), this study is more locally-focussed. However, where such theories might affect production strategies (such as the cultivation of cash crops or luxury goods for the urban market) they must be taken into consideration.

2.2 The nature of evidence for Roman farming and rural settlement

Now that the historical context and theories regarding land exploitation have been briefly discussed, the next stage is to discuss the types of evidence there are available for the study of Roman agricultural practice. These can be divided into broad themes: archaeological and historical evidence for agricultural tools and farming practice, the nature of the natural and cultivated landscape, and evidence derived from excavation or field survey in rural areas. The final theme concerns what types of area were considered desirable for estate location by the Roman agronomists, evidence which is extremely useful for creating models of possible farming strategies.

2.2.1 Tools and techniques

A number of sources are available regarding methods and techniques of Roman farming: a wide variety of agricultural implements (or representations of these) are known from antiquity, in addition to archaeological and historical evidence regarding farming practice. By the Roman period, farming technology had developed to a sophisticated level, with farmers using iron tools, ploughshares, and other similar equipment. A number of different plough types were available to the Roman farmer, with the use of heavy and wheeled ploughs in the Empire, although only the light plough was used in Italy itself (Forni 2002: 196-198; Blumer 1964; van Joolen 2003: 108 for a description of plough types from the Chalcolithic to the Roman period).

Ploughs had long been in use by the Roman period, and this can be demonstrated by numerous artistic representations. These include a model from Arezzo of a ploughman with oxen dating from 400 BC (Figure 2.2), and a later representation from Civita Castellana of two oxen pulling a plough, dating from the 3rd to 2nd century BC (Forni 1990: 303-306, 297; in van Joolen 2003: 108). The plough seen by Virgil in Rhaetia is described in detail in the *Georgics* (1.169ff), and has been reconstructed from this description (Figure 2.3). Preserved specimens, however, are less common, with the most famous being a very early complete plough found during excavation in Lavagnone in Brescia and dated to around 2000 BC (Figure 2.4; Perini 1982; in van Joolen 2003: 108).

Figure 2.2 The Arezzo Ploughman, 400 BC, Rome, Museo di Villa Giulia cat.16 (Bonamici 2000: 74)

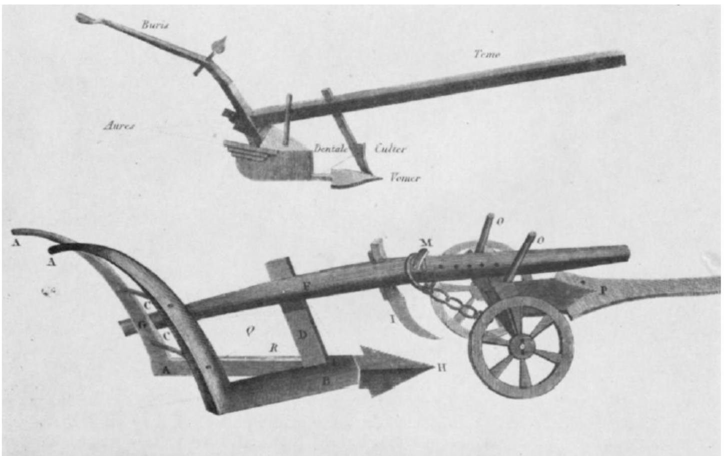


Figure 2.3 An 18th century reconstruction of the Virgilian plough (Fussell 1967: 22, fig. 4)

Figure 2.4 The Lavagnone plough, dating from 2000 BC (Cattedra di preistoria e protostoria and Universita' degli studi di Milano 2001)

Other types of agricultural technology were also in existence in pre-Roman times. Aside from tools themselves, larger-scale construction works contributed to the agrarian life of Roman Italy. For example, the system of *cuniculi* present under much of the study area provided the region with a very sophisticated drainage system from the Etruscan period onwards. *Cuniculi* were extensive underground passageways cut into the soft volcanic rock prevalent in the region, and were used for collecting ground water, controlling and lowering lake levels, irrigation and water power, and other uses as well as for drainage (Judson and Kahane 1963).

Practices such as the diversion of water, manuring and fallowing systems also occurred as early as the Neolithic and Bronze Age (Forni 2002: 198). Control of water is an important factor for this analysis: in Chapter 4, access to water by Roman agricultural sites is assessed in more detail. However, the limited available data on the location of such works means that, though we know from archaeological studies about the draining of, for example, Lake Baccano for use as agricultural land in the early Roman period (Potter 1979: 21), it is not possible to know in great detail the effect such practices would have had on lake and river levels more generally.

As regards farming regimes, epigraphic and other associated types of evidence are available to enhance our understanding of Roman agricultural technique, for example which crops were planted and when. The most important of these are the agricultural calendars. These come in a variety of forms and show the activities of a farm at the time they are supposed to be performed, the most famous being the *Menologia Rustica* (*CIL* VI 2305 and 2306). These two inscriptions (the *Colotianum* and *Vallense*) were probably the result of long farming tradition, based on a pre-Julian calendar, and are thought to date from the 1st century AD (Frayn 1979: 47-48). They describe the annual activities of a small farmer of mixed husbandry: tasks include harvesting, sheep shearing, and grape gathering (Figure 2.5). The full transcription of these calendars is in Appendix I.

The mosaic calendar beneath Santa Maria Maggiore in Rome dates from the first half of the 4th century AD. It is incomplete, but features a list of dates for each month, with festivals and the work to do be done on the farm. This was accompanied by wall paintings that depicted the activities appropriate to each month (Frayn 1979: 49). These calendars provide an insight into the various activities that took place on a Roman farm annually. As illustrated above, the *Menologia Rustica* provides evidence of a mixed economy, and presents an alternative to the traditional view of the countryside as one dominated by the vast grain or ranching estates of the ancient sources. Such calendars may therefore be included in the models used to determine potential production strategies and probable workloads of Roman farmers.

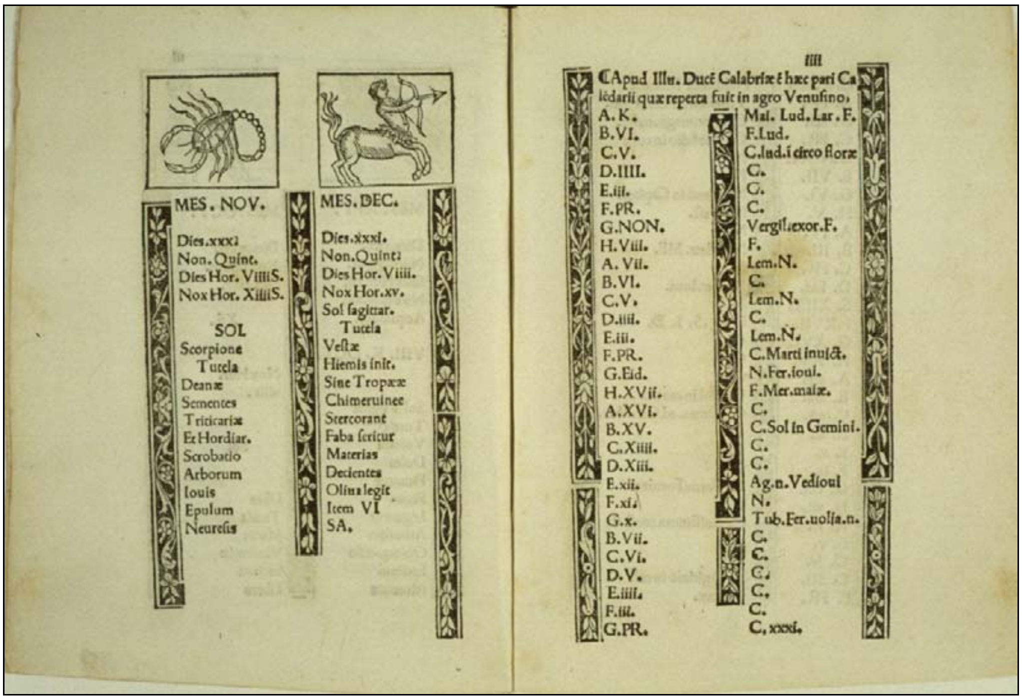


Figure 2.5 Printed version of the Menologia Rustica (Pomponio Leto, Rome: Iacopo Mazzocchi, c.1507)

Archaeological evidence aside, a wealth of information is also available through the study of Roman texts. From this period a variety of ancient texts are available either mentioning or explicitly dedicated to aspects of agricultural practice. These texts have formed the basis of all the major studies of Roman farming (White 1970a; Frayn 1979; Spurr 1986a). They provide important insights into the workings of a Roman agricultural estate, the operations carried out, and aspects such as yields, storage, and manpower, from which the generally high level of sophistication of Roman agricultural technique can be inferred. These texts include dedicated agricultural handbooks by Cato, Varro and Columella, encyclopaedic work by Pliny the Elder, and the poetry of Virgil and Horace.

It has been argued that such historical texts may be untrustworthy in their depiction of rural life (Grant 1995; see Jenkins 1991 for general deconstruction of historical texts), and as such may not be a reliable source of evidence for reconstructing ancient farming practice. The agricultural handbooks do not present a full range of farming practices as they primarily concentrate on villa-style agriculture, whilst the poetic sources could be giving an idealised view of rural life (Frayn 1979: 13). However, this study is not aiming to assess the accuracy of these sources. They are used to provide the basis for a model of Roman production in order to investigate the effect on the population supported. If practice was as specified by these writers, then what would the effects have been on production levels?

The first of these texts is *De Agri Cultura* by Cato the Elder. Written in the mid-2nd century BC, this constitutes the earliest written evidence regarding Roman practical farming in antiquity. His work has been criticised for defects in presentation, frequent errors, contradictions and so on, yet according to White (1970a: 19-20) he demonstrates an "*abundance of shrewd common sense and practical farming knowledge*". His rural upbringing in Tusculum may have contributed to this, and as a young man he is said to have worked alongside his own labourers in the fields (Plutarch *Cato Maior* 3.2). His work is certainly heavily influenced by his belief in frugality, discipline and high moral standards (Mellor 1999: 17-18), though this aspect may be considered a detractor from its accuracy. Indeed, this part of Plutarch's account has been described as a form of "*imaginative embroidery*" (Astin 1978: 9; in Rosenstein 2004: 195, n. 19), particularly as Cato was later said to have taken part in those activities he spoke out against in this work, such as money lending and trade (Plutarch *Cato Maior* 21.5-8; Niquet 2000: 122-123). Whilst the sections of text proclaiming moral respectability may be dubious, however, the content dealing with agricultural practice is more of interest to this study. Much of Cato's text deals with the organisation and management of slave-staffed estates, though White (1970a: 19-20) was quick to point out that this must not be used as evidence against the continuance of other forms of agriculture, subsistence farming for instance (see Section 2.1). Cato has been accused of having a limited objective, with no eye to experimentation or reference to new ideas or processes, yet he still holds a secure place in later tradition (White 1970a: 20, 35), indicating how well-regarded his work was by contemporaries and later writers in this field.

Varro published *De Re Rustica* in 37 BC. This work is more detailed than that of Cato, but again is tainted by aspects of his work that are interpreted as moralising rhetoric, contrasting town against country, "*vice against virtue, modernity against ancestral values, luxury against industry*" (Wallace-Hadrill 1991: 249). Varro has been accused of being merely an "*armchair theorist*" with too much reliance on Greek sources and little practical experience (Gummerus 1906; in Spurr 1986a: xi), but both Spurr (1986a) and White (1970a) argued that this was untrue. Varro's work has been described as immensely superior to that of Cato, based on practical knowledge and tried experiment (White 1970a: 24). He is regarded as a credible source based on his experience both on his own estates and as a member of the board of commissioners to distribute land in the *Ager Campanus* in 59 BC. Varro's criticisms of previous writers, including Cato and Theophrastus, and his advice regarding experimentation are also argued to add to his credibility (Spurr 1986a: xi-xii).

Columella wrote *De Re Rustica* some time in the 1st century AD. This study is aimed primarily at slave-staffed estates and was by far the most systematic and also longest of the surviving texts on agriculture. It is believed to be the product of his practical knowledge, with precise technical detail superior to any of his predecessors (White 1970a: 26-28). He owned farms in Latium (at Ardea, Albano and Carsioli) and one in the study area, near Caere (modern Cerveteri) (*Rust*. 3.9.2; 3.3.3), and he is generally regarded as a reliable source for estate-style agriculture. Columella, however, is argued to have written in an 'Augustan' (rather than Neronian) tradition, and was "*concerned to represent and repair early Imperial society in exactly the terms outlined at the beginning of Julio-Claudian rule*" (Milnor 2005: 241).

> *The farm* [is not understood] *just as a site of agricultural work, but as a place of moral and ethical rectitude where, if they so chose, contemporary Romans could reclaim ancient values which had made their state great.*
>
> Milnor 2005: 254

It has also been suggested that Columella might have played up the profitability of certain forms of agriculture (namely viticulture) at the expense of arable crop cultivation (Duncan-Jones 1962: 70, n.66; 1982: 34ff; see also Carandini 1983: 187). Nevertheless, the work shows significant development and refinement of technique since the time of Cato and contains a great deal of information applicable to the models used here.

Technical writings from the later Imperial period are scarcer and tend to consist mainly of re-workings of the earlier sources. These include the tracts of Palladius (4th century AD) and the Byzantine compilation known as the *Geoponika* which was written in the 6th or 7th centuries AD, and revised *c.* AD 950 (White 1970a: 30-32). These texts are not used here as they are not contemporary with the period of study. However, they do demonstrate that the earlier works of the agronomists were still considered applicable to the agrarian life of later times.

Other works on agricultural topics, also with their own associated problems, include the poems of Virgil (late 1st century BC) the *Eclogues* and the *Georgics*. These poems, though by their nature obscuring certain practicalities, still include much detail on farming practice as well as mentioning many problems that would have beset the Roman farmer.

> *…vile blight*
> *Attacked the stalks, and the shockheaded thistle sabotaged fields:*
> *Crops fail*
>
> *Georg*. 1.150-152

> *And various kinds of vermin play there [on the threshing floor]: often the wee mouse*
> *Builds underground his grange*
> *… and all the manifold pests*
> *Earth breeds; the enormous heap of spelt is spoiled by the weevil*
>
> *Georg*. 1.181-185

It has been suggested that, in doing so, Virgil was attempting to raise the status of agriculture (Frayn 1979: 13-14, 43). He was, however, also criticised by contemporaries: as stated by Seneca (*Ep*. 86) his aim was "*to delight the reader* [rather] *than to give instruction to the farmer*". The poems have been described as "*a very personal statement about Roman values and about the nature of ideal and real existence*" (Dyson 1992: 111-112), and as such they must be treated with caution. Yet, later technical writers acknowledged Virgil as an authority. Spurr noted that, though Seneca made his statement after seeing agricultural practices that differed from those described by Virgil, we should instead doubt Seneca's own agricultural knowledge and, indeed, his knowledge of Virgil. Added to this is the fact that there exists regional variety in farming practice (Spurr 1986b: 165-166). Furthermore, even in a brief examination, Virgil was shown to have been accurate in half of the operations under discussion (White 1967-68; 1970a: 40). The *Georgics*, therefore, are a problematic, but not useless, source for use within quantitative modelling.

Pliny the Elder in his encyclopaedic work, *Naturalis Historia* (1st century AD), comments in detail on various aspects of agriculture. His work is of great importance, providing a similar range of information to the early agronomists, with comments on yields, manpower, and so forth. However, it has been noted that he is extremely uncritical of his sources and is prone to moralising rhetoric (White 1970a: 28), ideas such as the simple subsistence nature of early Roman life. For example, the consul and farmer-general Cincinnatus was a highly influential figure, and according to Pliny (*NH* 18.20) was called from his farm of only four *iugera* to become dictator and lead the Romans against the Aequi in 458 BC. This idea was emphasized by Garnsey (1999: 78) when he stated that the:

> *myth of archaic Rome … was centred on the idea that their empire-building ancestors lived lives of extreme poverty and frugality, and they confronted this legendary world with their own society, decadent from top to bottom.*

Despite such criticisms, Pliny's casual observations on the economics of farming can still be informative (White 1970a: 35).

The major problem with all of these ancient texts, however, is that they refer almost exclusively to forms of large landholding, most likely producing market-oriented crops, rather than the more modestly-sized mixed units often found through field survey (White 1988: 220; and see Section 2.2.5). Also, these works often portrayed the ideal of self-sufficiency for these estates, where everything required (such as vine props, pottery, fodder) was ideally produced 'in-house' (e.g. Cato *de Agr*. 4.30.1), despite being impractical on many estates.

This would mean that any surplus production for the market would largely result in profit rather than having to exchange for raw materials.

Although Pliny the Elder claimed that he wrote for *rustici* (*NH* 18.323), the only textual information regarding farming practice on small farms comes from the 1st century AD poem *Moretum*, often attributed to Virgil. This poem describes a Roman peasant named Simylus whose poverty means that he cannot afford to eat meat, instead growing cereals and processing his own bread. He does, however, supplement this bland diet with cheese and the titular *moretum* – a paste made from garlic, herbs, salt, oil and vinegar. He also grows vegetables such as cabbage, beet and lettuce in a kitchen garden. However, these are mostly for sale rather than his own consumption, so that he might purchase other essential items (Garnsey 1988: 56; 1999: 25-26). Simylus also owns oxen which he uses to plough his fields, although it is not stated how many *iugera* of land he owns. This description of a mixed farming economy, if at a very low level, is compatible with the image of smallholders obtained from other archaeological sources.

Despite all the available sources, there are still very large gaps in our knowledge of agricultural history. Using written histories of this sort is problematic, as they are more often a reflection of "*contemporary sentiment*" than "*sources of social fact*" (Jongman 2003: 105), and almost always written from an elite viewpoint. Peasants and slaves, who did not write their own history, were the primary agricultural producers in this period. We therefore cannot hope to have an unbiased view of their position within the Roman economy, and only further archaeological evidence can provide further insight into the lives of the smaller farmers (see Sections 2.2.4-5).

Using the works of the agronomists and other Roman writers in historical or archaeological studies has also been criticised due to their role in literary debate. Dyson (1992: 22) described these texts as "*weapons*" used in contemporary discussions regarding the optimum use and improvement of agricultural resources and how to strengthen the economic base of the Roman elite. As such, they must be approached with caution, particularly regarding the promotion of certain types of economic strategy (particularly viticulture). Nevertheless, they provide an invaluable, if biased, picture of farming, and the figures provide a solid base for quantitative modelling of different agricultural scenarios.

Despite the rhetorical nature of such texts they still provide an abundance of information of farming practice. Frayn (1979: 14) puts it succinctly when she argues for the use of agricultural writings in such analyses.

> *Do the writer's facts generally tally with those given by other ancient sources? Are they probable in view of what we know of Italy before, during and after the Roman period?*

As long as the texts are used in conjunction with such checks then their use in quantitative analysis can be argued to be a worthwhile exercise.

Although there are many problems and uncertainties associated with using ancient sources in quantitative modelling they are by no means useless. The type of modelling approached here provides an opportunity to quantify the evidence presented in these sources and to test the effects they would have had on the productive capacity and demography of the area. This is discussed in more detail in later chapters.

2.2.2 The natural and cultivated landscape

A comparison of rural landscapes or changes in a region's land use cannot be fully understood without considering the natural environment and its functional relationship with agriculture (Mørch 1994: 108). Evidence regarding the natural environment and economy of the Roman countryside can be gleaned from various sources: as well as the historical evidence discussed above, the most obvious source is environmental archaeology. These data, used together, can provide clues towards what types of crop were grown, and what the landscape might have looked like in this period.

Although environmental evidence is one of the most important types of data in this field, relatively little work of this nature has been attempted within the study area. It is potentially an incredibly important source of evidence and could contribute information regarding when and where different types of crops were grown, as well as data on aspects such as deforestation, erosion, alluviation and climate. It may also yield new insights into aspects such as the introduction of domestic animals and the appearance of 'wild' mammals associated with agro-pastoral systems (Walsh 1999: 3). The application of environmental archaeology techniques to the Mediterranean has proved complex (Walsh 1999: 1) and as a result there are only a small number of studies that can be drawn upon.

One of the most comprehensive environmental studies of Italy comes from Heraklea, near the city of Metapontum in southern Italy. Evidence provided by a set of bronze tablets (dating to the late 4th to early 3rd century BC) describes in detail the agricultural lands and crops of the area, giving an insight into the types of plants and crops in existence in Italy at this time (Carter *et al.* 1985: 290). Subsequent excavations at Pizzica-Pantanello, in the same region

(Carter 2001a; Costantini 2001) produced a detailed picture of the flora and fauna of the region which can be compared to that suggested by the tablets.

To summarise, the Heraklea tablets imply that barley was the most important crop, given that rents were quoted in measures of this (using the Greek measure of *medimnoi*), with no mention of wheat. The organic material, however, shows wheat to have been the most abundant crop, at least in this particular area. The tablets also mention olives, figs and grapes, all of which were present in the organic deposit, but make no mention of legumes despite their presence at Pizzica-Pantanello (Costantini 2001). A large number of animal bones were also found in the deposits, with one sample highlighting major changes in land use, via the animal populations, from an agricultural to pastoral economy. This was used to support the theory of the growth of *latifundia* in this area (Carter 2001b; Cabaniss 2001).

The data from Metapontum highlight some interesting problems in using solely epigraphic or textual evidence to attempt any reconstruction of ancient landscapes. The organic material demonstrates correlation with plant types listed by the agronomists as being typical on Roman estates (see below), but does not tally with what is known of that particular area from the inscriptions on the bronze tablets. The importance of a combination of approaches is therefore highlighted, as the organic material recovered from excavations in the area has both supplemented what was already known of the area from the textual and epigraphic data, and in some cases contradicted previous assumptions. This enables us to anticipate potential problems of relying heavily on written records in this study area.

The areas of South Etruria and Sabina are much poorer in terms of environmental study, although a few works do exist (see below). It is therefore necessary to firstly return to the ancient sources, to determine what types of crops were likely to have been grown in the region. The Roman agronomists provide evidence for which crops were favoured and on which soils they should be cultivated, but this is not always directly transferable onto landscapes in different regions. However, the geography of certain regions will be clearly more favourable to certain types of crops, for example specialist wine regions or the vast grain lands of Sicily.

According to the sources, Etruria was known in the Roman period as an area of extensive cereal cultivation (e.g. Columella *Rust* 2.6.3, Pliny *NH* 18.66, 18.86-87, and Pliny *Ep*. 5.6.10-12). On a number of occasions in the 5th century BC, Etruria had been one of the grain suppliers helping to alleviate shortages at Rome (e.g. Livy 2.34; 4.25; 4.52; Dionysius of Halicarnassus *Rom. Ant.* 7.1.3; 12.1).

> *… the consuls provided for the emergency by sending men in various directions to buy corn. They penetrated not only along the coast to the right of Ostia into Etruria, but also along the sea to the left past the Volscian country as far as Cumae…Some corn came from Etruria up the Tiber; this served for the support of the plebeians*.
>
> Livy 2.34

> *The largest supplies were brought down the Tiber, through the ungrudging exertions of the Etruscans.*
>
> Livy 4.52

However, less information is available regarding the area of the Sabina across the river, which is geographically very different (see Chapter 1) and is thought to have favoured olive cultivation, as demonstrated by the modern-day land use as well as references in ancient sources.

The olive tree … does not like either low-lying or lofty situations but prefers moderate slopes such as we see in the Sabine territory in Italy
Columella *Rust*. 5.8.5

Aside from the major economies of arable and olive cultivation, ancient sources regarding alternative land use and economies of the study area are diverse, as may be expected for such a large and varied area. To illustrate, Propertius (4.10.29-30), in the Late Republic, described the Etruscan city of Veii:

Alas, ancient Veii! …now within your walls sounds the horn of the loitering shepherd, and men reap cornfields over your graves.

Although a highly romanticised image, this passage does imply both arable and pastoral activities in the area. Potter (1979: 93, 100) noted that Veii was only noted later on by Martial for the poor quality of it wine – "*Thick lees of red Veientan*" (Martial 1.103.9) is the drink of a poor man – and indeed Roman vine trenches have been found in the area during excavation (Kahane *et al.* 1968: 158).

Contrary to the picture of the study area as one devoted to cereal cultivation, careful inspection of the sources demonstrates a mixed economy was present. To illustrate, the cultivation of fruit and vegetables is attested at Crustumerium (Pliny *NH* 15.53), Nomentum (Martial 13.42; Columella *Rust*. 3.3.3), and Rome (Pliny *NH* 19.77, 15.97). Further north, Falerii Novi was described by Ovid in the late 1st century AD as the "*fruit-bearing Faliscan town*" (*Amores* 3.13). Practices such as bee keeping (Varro *Rust*. 13.16.10-11), or the raising of fieldfares (a type of thrush) in the Sabina (Varro *Rust*. 3.2.15, 3.4.2) are also mentioned. These are examples of *pastio villatica* – the production of luxury foodstuffs such as thrushes, dormice and eels for the market. Studies such as that by Morley (1996) have emphasised the production of luxury produce such as flowers, vegetables, honey, and *pastio villatica* in the study area. Its alleged presence is suggested by the proximity of the market at Rome and the increasing supply of Rome's grain by the Provinces. The textual references to these have been compiled into a map by Morley (1996: 84) showing many towns in the study area and the economies associated with them in the sources. This map has been augmented with additional information and is shown in Figure 2.6. This is not to say that cereals were not the major staple crop of the area, merely that farms and estates were likely to have diversified to some extent.

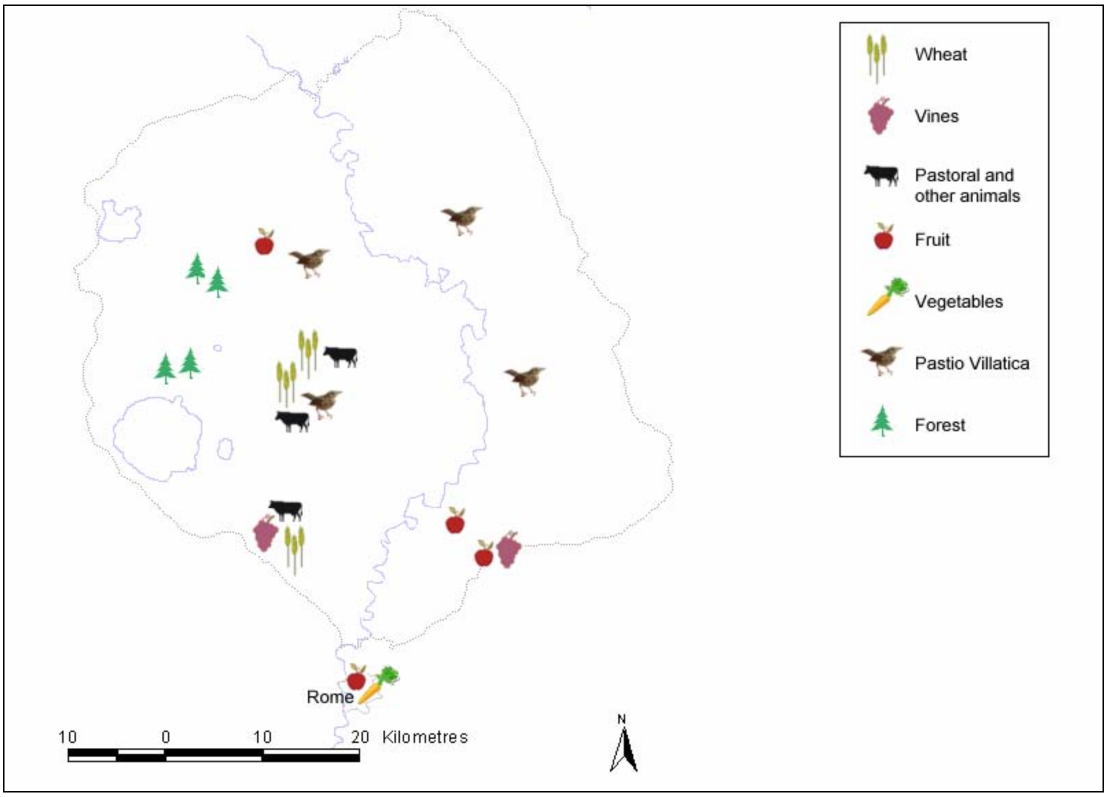


Figure 2.6 Roman land use in the study area, known from textual sources and archaeological data (after Morley 1996: 84)

Other natural areas described in the sources include areas of woodland and forest. Livy (9.36) described the Ciminian forest near Sutri as "*pathless and terrifying*", and the existence of extensive woodland is substantiated by pollen evidence from the area (Potter 1979: 23). Few examples of pollen analysis are known from the study area, and few other environmental analyses have been carried out, which is unfortunate given the wealth of information this type of analysis provides about landscape changes and species of plant present. Most palynological work has been carried out on lake sediments in the region, for example, the studies at Baccano (Bonatti 1963), Lago di Monterosi (Hutchinson 1970), and Lago di Vico (Frank 1969). There have been few published reports of pollen recovered from excavated contexts: two examples are those from the excavations at Narce and at Monte Gelato in South Etruria (Figure 2.7; Potter 1976; Potter and King 1997).

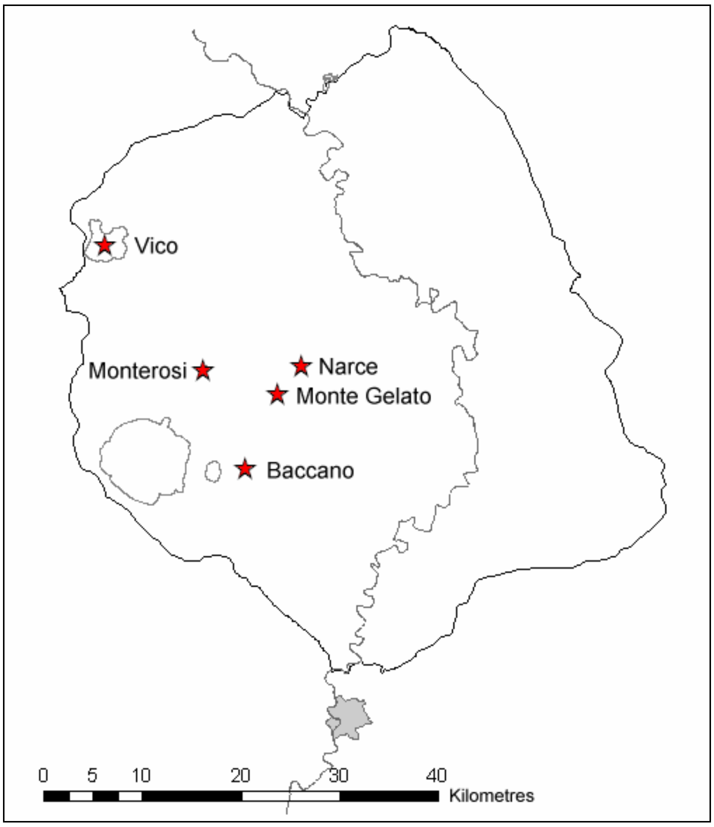


Figure 2.7 Location of pollen cores and plant remains from excavation

Due to a heavily wooded area surrounding the lake at this time, the pollen sequence from Lago di Monterosi is predominantly made up of tree species. These include the dominant oak, along with species such as chestnut and beech, amongst others. There are also smaller herbaceous plants such as those from the Rose and Daisy families. The presence of the *gramineae* family (grasses and cereals) as well as nettles imply a certain amount of clearance and disturbance to the ground: this is probably associated with grazing and a certain amount of agriculture (Bonatti 1970: 29, tab. V-1).

For the Vico sample, no ^{14}C dating was attempted due to a lack of suitable material, but the sample is thought to be analogous to that of nearby Baccano (Frank 1969). From the Baccano sequence we know that, again, oak forest was dominant for most of the sequence, which runs from 9-10,000 to 2000 BP (i.e. up until the late Republican period). As well as this we also have nettles, which signify possible grazing, as well as cultivated species of cereals and plantain species which have been associated with primitive agriculture (Bonatti 1970: 31).

The problem with using pollen sequences derived from lake sediments is that different types of pollen travel further than others, depending on their type of pollination (i.e. by wind or insect). A variety of pollen dispersal models exist which demonstrate the distances that certain types will travel (Moore *et al.* 1991: 12-14). It is therefore likely that, in the case of the South Etrurian lake samples, as the areas immediately around it were not fully cleared and cultivated until quite late on, they do not represent a full picture of what was happening at the Roman settlements of the region. As well as this, some types of plant and tree produce more pollen than others, thereby risking over- or under-representation within a dataset (Moore *et al.* 1991: 181). This demonstrates why it is important to gain archaeobotanical assemblages from excavated sites and that the results must be treated with some degree of caution.

The small sample of charred plant remains from an Early Imperial context in excavations at Mola di Monte Gelato reveals that cereals accounted for over 50% of the total assemblage, with wheat being the most common, although barley, millet and oats are also present. Legumes comprise around 33% of the sample. Vetches are also present, which could have been either arable weeds or forage cultivation. Two olive stones were also found, although it is unsure whether these were cultivated on-site. The small sample means that it is impossible to establish the relative importance of individual crops (Giorgi 1997: 408-411), but the assemblage does go some way towards establishing likely subsistence strategies. Plant remains from Narce, although mostly from a pre-Roman context, also provide an insight into the nature of the environment: cereals, particularly emmer wheat, are dominant in the sample, and legumes also form a small percentage. The increase of weed remains between 12th-9th century BC has been interpreted as an increase in agricultural intensification and a shortening of the fallow (Jarman 1976).

Faunal remains from Monte Gelato indicate the dominance of pig breeding, probably with a marketable surplus, although a number of other species are present. These included sheep, goat, ox, deer, hare, dormouse, chicken and thrush (King 1997: 383-385, 398; West 1997: 403-404), whilst a fishpond excavated on the site attests to the presence of eels (Cartwright 1997: 404). The animal bone samples from Narce represent primarily domestic animals. Sheep and goats are by far the most common, making up around half of the sample, whilst cattle and pigs make up the remainder. There were also a few remains of dog and horse. This proportion of domestic animals remained constant from the Iron Age to the Roman period (Barker 1976: 297). The sample is interpreted as representing the raising of large numbers of caprines for products such as dairy and wool, with pigs the major source of meat. Cattle are thought to have been raised for traction and also possibly for dairy products (Barker 1976:

302). Animal husbandry and its contribution to diet are discussed more fully in Chapter 8, and the Monte Gelato assemblage provides an interesting basis for modelling.

The environmental studies from the lake cores imply a prevalence of open ground supporting cereal crops during the Roman period, declining only with a reduction in settlement numbers in the early medieval period (Potter 1979: 24). This suggests that the majority of farms and estates were not, as has been inferred (see Section 2.1), moving away from the production of cereals for subsistence and towards the production of market-oriented cash crops such as vines and olives. This theory, however, can only be applied to a limited area and only the further study of archaeobotanical remains from a more dispersed area may elucidate the situation any further.

Although mixed farming strategies were followed, as evidenced both by the archaeobotanical and faunal studies (particularly from the excavated contexts), cereals are likely to have remained the dominant economy for the area. To illustrate, over 100 grain mills and quern stones were found within surface scatters during the South Etruria survey (Figure 2.8). This has been taken to support the view that this area was primarily a cereal-producing area (Potter 1979: 126). Although this figure is low compared to the numbers of identified rural sites in the study area (over 1,000), it must not be forgotten that millstones and querns are heavily reused over long periods of time, and that field survey as a method is not likely to be the best indicator of frequency.

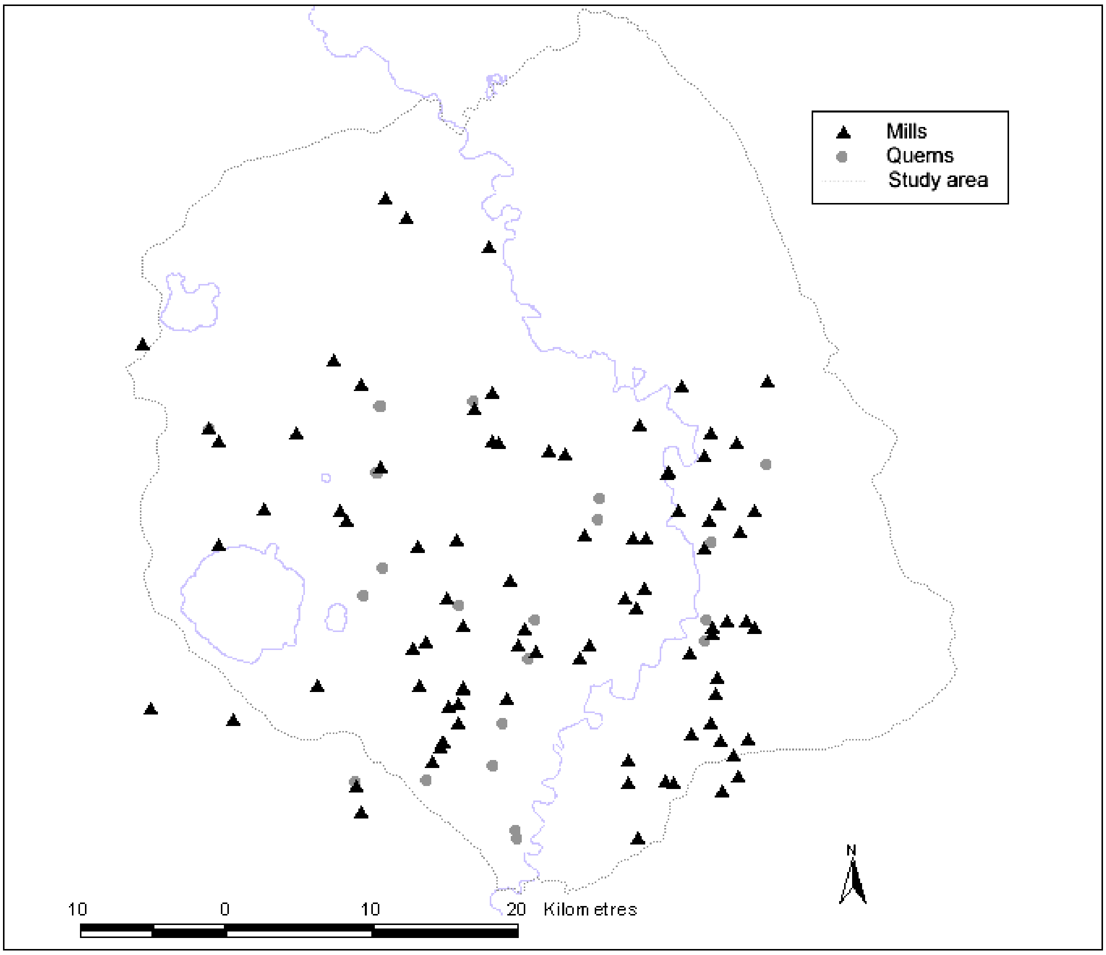


Figure 2.8 Distribution of millstones and querns in South Etruria (British School at Rome)

Increasing imports from the provinces would have serviced the needs of the huge urban population of Rome as well as the needs of the military, but rural populations and smaller urban centres were more likely to have relied on local production (de Ligt 1990: 35ff; Hopkins 1980: 101-102; Jongman 1988: 78-79, 131). De Ligt, in particular, argued for considerable rural exchange: small farmers were not just producers but consumers of goods and services (1990: 25). To purchase such goods required a surplus and, like Simylus (Section 2.2.1), could have produced specific goods for the market, or could have relied on a surplus cereal crop to sell to non-producers. A large percentage of the country would have needed to feed itself through the production of a staple crop, with a large proportion of the available land consequently having to have been given over to cereal crops.

All of this data contributes to our understanding of the natural and cultivated landscape of the study area. Although cereal production was likely to have been dominant, we have evidence attesting to the existence of alternative strategies such as animal-raising and *pastio villatica*, which can supplement the diet by providing essential minerals and proteins, or merely by providing variety. As such, this information can be used to model a variety of possible subsistence strategies and the subsequent production of the area (see Chapter 8)

2.2.3 Rural excavation in Central Italy

A number of excavations and landscape surveys have taken place over the past century that are of direct importance to this study. The implications of such studies on ideas of settlement and demography in the Roman period impact on our idea of the countryside and its relationship with urban centres. These will be assessed in the light of the evidence discussed above.

Many excavations of rural sites have taken place in Italy, most of these being primarily interested in high status villas (e.g. Settefinestre below). This is not surprising given the fact that villas are more archaeologically conspicuous and more likely to turn up more valuable artefacts than smaller sites. Furthermore, the investigations have been predominantly focused on the villa complex itself, rather than its territory and resources. This supported the view of the countryside from a purely aristocratic standpoint, ignoring the concept of territory and the size of landholdings. The rural reality would have been much more diverse than a landscape of large villa estates, with a greater number of smallholders of varying degrees, and more recent excavations in the region have begun to focus on these smaller agricultural holdings (see below). Nevertheless, we have gained a great deal of important information regarding the production and distribution of goods.

Excavations such as those at Settefinestre in the *Ager Cosanus* (Carandini 1985), San Giovanni di Ruoti in Basilicata (Small and Buck 1994), and the villas of Buccino in Salerno (Dyson 1985) have proved invaluable in a reassessment of Roman rural development in peninsular Italy. The excavation of greatest relevance to this study is Settefinestre, due to its proximity to the study area and its interesting implications for agricultural practice.

Settefinestre was first excavated in the 1970s, at the same time as a detailed topographical survey of its surrounding area in the *ager Cosanus*. From these studies it was argued that, in the 2nd century BC, this area was likely to have been dominated by small plots of approximately six *iugera* (1.5 hectares), which were later replaced by large villa complexes in the late second century to early 1st century BC. This process is thought to have been indicative of a change to absentee landowners and the use of slave labour (Carandini and Tatton-Brown 1980: 10). The villa of Settefinestre itself is thought to have been built in the second quarter of the 1st century BC, along with the nearby villas of Le Colonne and La Provincia, which are architecturally similar. They remained in use until their abandonment in the 2nd century AD. The main villa building of Settefinestre lies on the saddle of a hill covering an area of about 2,000m^2, but the entire complex covers approximately 25,000m^2. As well as the central residential villa, the complex has areas for manure storage, a kitchen garden, orchard, granary and oil and wine processing areas (Carandini 1985; Carandini and Tatton-Brown 1980: 11-13).

This excavation is vital for demonstrating the types of agricultural practice occurring on such estates at this time. The presence of a variety of agricultural activities argues against the idea of large-scale monoculture, and illustrates a mixed economy, which would enable a certain measure of self-sufficiency. The excavators interpreted the villa as being engaged in viticulture and surmised that the storage facilities could hold up to 15,000 litres (Carandini 1985: 165-168). Cereal production, however, was interpreted as its main pursuit, and the monumental granary could hold up to approximately 103,000 kg of wheat (Carandini 1985: 169-170). This is a huge store, though there is nothing to imply that *all* grain kept here was necessarily produced on site. A percentage could easily have been procured in exchange for other goods produced on the estate.

The Settefinestre excavation has been used to exemplify the practices advised by the Roman agronomists, and was said to be "*the best example of Varro's* villa perfecta" (Carandini 1985: 194; in Purcell 1988), but this does not mean that such enterprises were widespread in Roman rural society. It has been noted by Purcell (1988: 196) that the excavations at Settefinestre show the site to conform *so* well to the model farm illustrated by the agronomists that,

> *the excavators might perhaps have wondered what the significance of this remarkable phenomenon was, rather than taking their good fortune for granted.*

Whether or not this villa is 'too perfect', however, is not really the issue. The main danger would have been to assume that, as Settefinestre conforms, therefore all other villas must follow this pattern. However, rural production is likely to have been much more diverse than is suggested by the sources and these archaeological results, as shown by the studies discussed below.

There are thousands of rural sites known from field survey within the study area, and the South Etruria database contains a number of those that have subsequently been excavated. Many, unfortunately, have not been fully published (Figure 2.9).

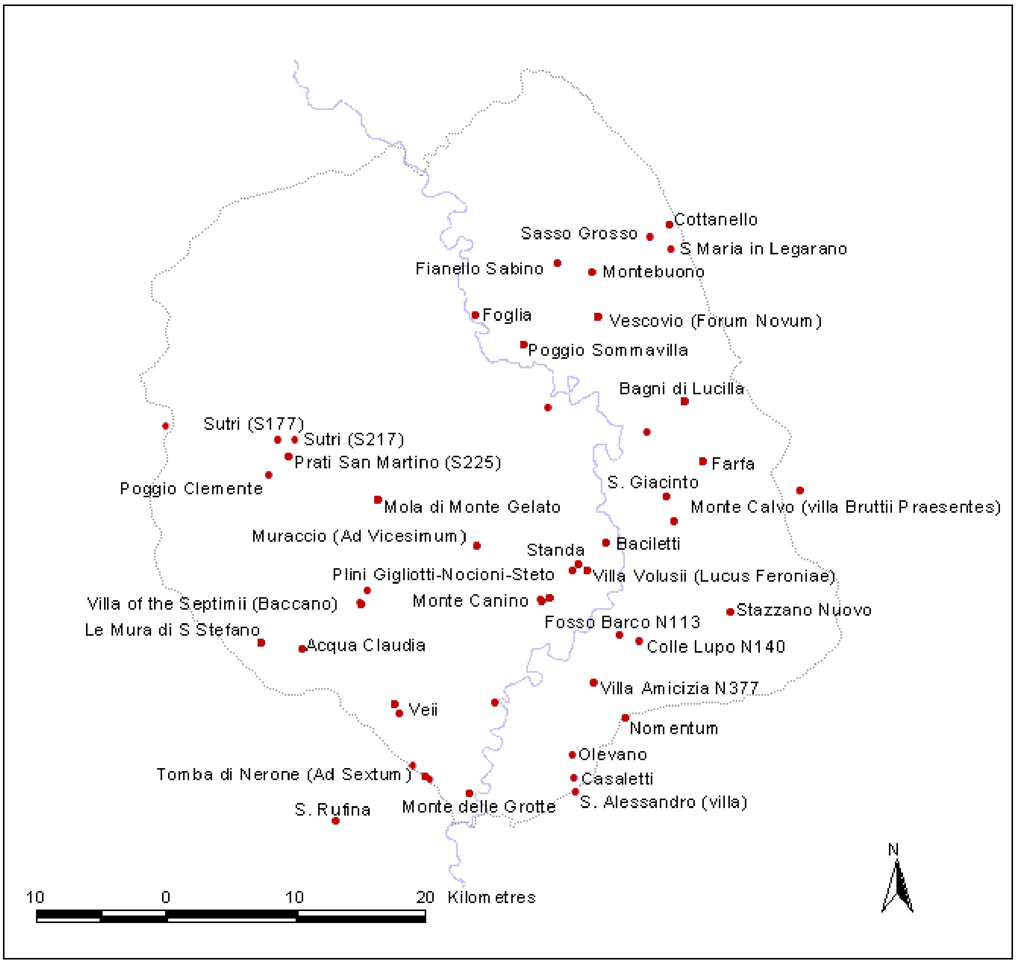


Figure 2.9 Location of excavated rural sites according to the South Etruria database (some sites have no names in the database and these have been left blank)

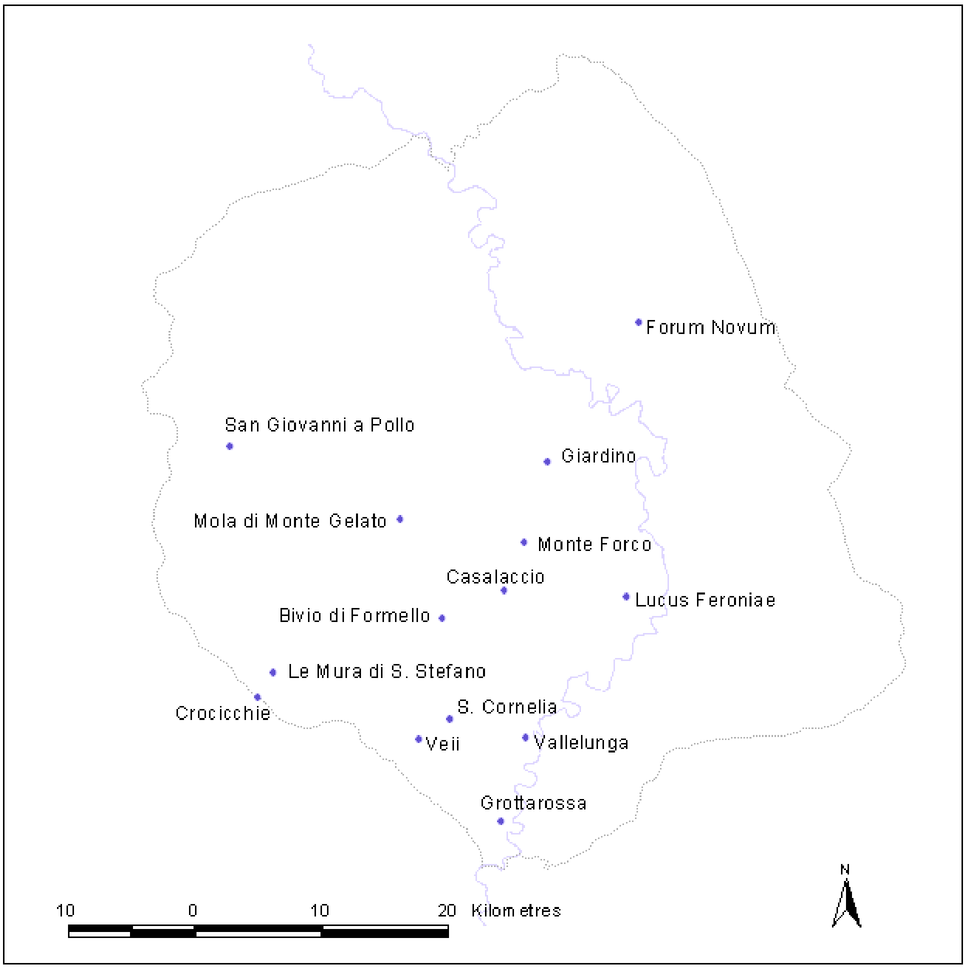


Figure 2.10 Location of sites mentioned in the text

The largest of the excavations within the study area is that of the suburban villa near the town of *Lucus Feroniae* (see Figure 2.10 for location). This was discovered and excavated during the construction in the 1960s of the Autostrade del Sole, a motorway that now runs through the study area. The villa is situated to the north east of the town and is known to have been owned by the *Volusii*, a wealthy senatorial family. It was built in the Republican period but was substantially improved in the Early Imperial period to become a grand structure. The villa incorporated residential areas and a bathhouse, as well as areas devoted to agricultural activities (Autostrade 1968; in Potter 1980: 74; Potter 1979: 130).

The Mola di Monte Gelato, discussed briefly above, was also the subject of a major excavation program in the area (Potter and King 1997). Despite its long occupation period from the Augustan period to post-medieval times, there is little evidence for agricultural production at the site, despite providing some botanical and faunal evidence. Evidence for *pastio villatica* exists (see Section 2.2.2) but no *pars rustica* was discovered, although this does not mean that one did not exist (Potter and King 1997: 421).

The villas of Giardino, near Sant'Oreste (Jones 1962: 183-185), S. Giovanni a Pollo near Sutri (Duncan 1958: 88-89), Casalaccio (Kahane *et al.* 1968: 138-144) and the rich sites in the region of Grottarossa (Jones 1963: 146) were all sites of similar wealth to the suburban villa of *Lucus Feroniae*. However, their investigation has provided us with only partial plans and their development is not very well understood (Potter 1980: 75). The principal building of the villa at San Giovanni a Pollo was a courtyard house measuring 41-56m (Lyttelton 1980: 60). This was not of a grand scale, but must have been of reasonably high status as it had built its own *diverticulum*, providing easier access to the larger road network of this area. This also occurred at Casalaccio, connecting the villa to the Via Flaminia, also crossing a river, and at Vallelunga in the south-west *Ager Faliscus* where the Via Cassia was connected to a series of estates by a lengthy stretch of road (Potter 1980: 75; Kahane *et al.* 1968: 138, 157). In a similar vein, a bridge was built by a landowner named T. Humanius Stabilio over the Fosso del Forco. This improved communications for the major estates at the Bivio di Formello (Guzzo 1970; in Potter 1980: 75). These must have been high status sites if the landowners could afford to implement such a strategic resource. The building of roads and bridges was an expensive pursuit, although would inevitably benefit the community, as well as providing status for the benefactor responsible. It also highlights the importance placed on appropriate communication and transport routes for rural sites (see also Laurence 1999): this idea of proximity to transport networks being desirable is discussed further in Section 2.2.5.

Le Mura di Santo Stefano is situated in the valley of the Fosso di Santo Stefano, approximately two kilometres south of Lago di Bracciano, and has a paved approach road that is likely to have joined the Via Clodia (Luttrell 1980: 45). There are substantial standing remains, mostly of later periods, which have been studied in great detail (e.g. Whitehouse 1980). The villa had a long occupation history, and seems to have remained in use from the late 1st century BC into the early medieval period. In its earliest incarnation, the site was probably agricultural, although we have little evidence for this period. This was followed by a large high status building, constructed around AD 150. The following phases fall outside of our remit, suffice to say that it was a large complex, later associated with a medieval church from which its name derives (Whitehouse 1980: 113-114). Interesting Roman features of this structure include the main rectangular building block of Imperial date, which survives up to a height of around eighteen metres in places. A sunken *dolium* is *in situ* on the ground floor, indicating storage. There is also a possible cistern structure of Roman date, originally part of a larger complex of buildings, which has associated *dolia*. Various interpretations of the building have included a storehouse for estate produce, a *horreum*, the residential wing of a wealthy *villa rustica*, a tower building, or even a mausoleum or religious sanctuary (Lyttelton 1980: 53-60).

Although villas and farms are known in the Sabina from structural remains from surface survey (e.g. Muzzioli 1980) and inscriptions (Reggiani 1985), published excavations are relatively rare. One of the few rural sites to have been excavated on the east bank of the Tiber is the villa at *Forum Novum* (modern Vescovio). This suburban villa, located originally through the use of geophysical survey, lies in close proximity to the town (whose extent is as yet unknown). Subsequent excavations showed the villa to have contained evidence for *pastio villatica* in the shape of the large central fishpond, thought to have been designed to contain eels. This *piscina*, indicating elite status, is unique to the Sabine region and is comparatively rare elsewhere in Italy (Gaffney *et al.* 2004: 210; cf. the example at Monte Gelato, Cartwright 1997: 404).

All the sites discussed so far have been high status villas. However, there have been some investigations of smaller sites in the study area, although these are few. One example is the exploration of five sites along the Monte Forco ridge in the *ager Capenas* (Jones 1963: 147-158). These sites are thought to have been a series of smallholdings due to their proximity to each other and the nature of the landscape creating natural boundaries to small areas. Only one site (no. 154) has been investigated fully. Results showed a very small building with stone footings, built around 50 BC, probably as part of Caesar's veteran land allotments in the area. It seems likely that, as it was later converted into a wooden barn or stable, the building may have been absorbed into a larger estate. The associated plot of land is thought to have not been larger than ten *iugera* (2.5ha), with the actual amount of workable ground nearer to half that figure, due to the slope and scrub (Jones 1963: 149). Finds from the excavation were few and of low status. Only four metal objects were found, three of which were nails. The fourth however, was interesting as it was a curved piece of iron, thought to have been part of the head of a mattock. This makes it one of the few published examples of Roman agricultural equipment found within the study area (Jones 1963: 157).

Another smaller site is the small villa of Crocicchie, close to the Via Clodia. This was shown to have been a very modest site of the early Imperial period, probably with an associated outbuilding. This was enlarged in the 3rd century AD to include a simple bathhouse (Potter 1979: 134; 1980: 75-76). Monte Canino, in the *Ager Capenas*, was also an excavated agricultural building from the early Imperial period, which produced evidence for wine production. A wooden press, or *torcularium*, was discovered during the excavations in the early 20th century (Jones 1962: 161). Other evidence for wine production has also come from excavations at Santa Cornelia, which was later to become the centre for the huge papal *domuscultae* of the early medieval period. Excavations at this site, just to the north of Veii, uncovered vine trenches dating from the Early Imperial period (Potter 1979: 126).

What can be seen from these examples is that rural sites were diverse within the study area in the Roman period, not only in size, but also in function. Dyson (1992: 137) stated that there is no standard type of rural site, and that they may range from elegant wealthy villas full of luxury goods down to mud-brick buildings with few status objects. This difference is important as this affects the archaeological visibility of a site: we are probably seriously underestimating the amount of lower status sites in the area due to their fewer material goods, and in many cases they may have been lost completely.

2.2.4 Rural settlement and field survey

Field survey in Italy began with the work of the early topographers. Sir William Gell and Antonio Nibby collaborated on ground-breaking topographical studies of Rome and the Roman Campagna, recording the position and context of ancient standing structures (Nibby and Gell 1820; Gell 1834; Nibby 1837; all in Potter 1979). This area was also the subject of study by the Italian archaeologist and topographer Rodolfo Lanciani in the early 20th century (1909; 1925).

Aside from these early works, two important and influential studies within the study area are those of George Dennis and Thomas Ashby. Dennis popularised Etruscan studies through his topographical study of the standing features and tombs in the region – *Cities and Cemeteries of Etruria* (1848). This approach was continued for the Classical period in Ashby's *The Roman Campagna in Classical Times* (1927). For this study Ashby carried out an exhaustive study of the standing monuments and the traces of roads that linked them in the countryside near Rome. Simultaneously an Italian scholar, Tomassetti, was carrying out topographic survey in this area, although from a different perspective. His five-volume work, *La Campagna Romana, antica, medioevale e moderna* (1910-26), utilised documentary sources, though contained excellent topographic detail (Potter 1979: 1-3; Ridgway 1996: 483-4).

Other studies include the excavations at the Faliscan town of Narce by Pasqui and Cozza in the late 19th century. Although not strictly field survey, there was an attempt by the authors to set the excavations in its landscape context. This was done by mapping and describing other Iron Age centres within the region (Potter 1979: 2). In the 1920s Giuseppe Lugli, a student of Lanciani, began to draw up his *Carta Archeologica del Territorio di Roma*, and was one of the first contributors to the *Forma Italiae* series of landscape surveys, although this was not published until much later in 1962 (Richardson 1996: 701-2).

In recent years the study of small and medium sized rural sites has become more common, aided by the increase in archaeological field surveys carried out in Italy over the last half-century. Figure 2.11 shows the location of a number of the large-scale field surveys that have taken place in Italy over the last fifty years. These include surveys at Luni (Mills 1981), Cosa and the Albegna Valley (Dyson 1981; 1978; Attolini *et al.* 1991), Sangro Valley (Lloyd *et al.* 1997; Lock *et al.* 2000), Fregellae (Coarelli and Monti 1998), the Biferno Valley (Barker 1995a; 1995b), the Liri Valley (Wightman 1981), the San Vincenzo Survey (Hayes 1985; Hodges 1988), Tuscania (Barker 1988; Rasmussen 1991), Rieti (Coccia and Mattingly 1992) and not least the South Etruria surveys (Duncan 1958; Frederiksen and Ward Perkins 1957; Jones 1963; 1962; Kahane *et al.* 1968; Potter 1979).

Figure 2.11 Locations of major field surveys in Italy

Figure 2.12 Location of the South Etruria surveys within the study area

Due to its strategic importance within the hinterland of Rome the study area, in particular South Etruria, has been subject to a number of studies under the auspices of the larger 'South Etruria Survey' (Figure 2.12). The major source of data used here is material collected from these surveys, reappraised in the light of new dating sequences. These early studies mainly concentrated on standing remains and the elite presence in the landscape. It was not until the 1950s, however, that our knowledge of the Tiber Valley landscapes diversified. A series of surveys were carried out at this time by the British School at Rome, instigated due to the extensive land reform schemes being introduced in Italy at this time. These reforms brought huge areas into intensive cultivation that had remained as pasture for many years, and at the same time also saw the introduction of mechanised deep ploughing in these areas. This, together with the rapid expansion of towns, the establishment of new suburbs, and modifications to the road network, meant that a programme of intensive 'rescue' survey was needed to record these endangered sites (Frederiksen and Ward Perkins 1957; Duncan 1958; Jones 1962; 1963; Kahane *et al.* 1968). These initial surveys were later continued by a number of scholars (e.g. Hemphill 1975), although were not fully published. This program of work was revolutionary in its scope, particularly as the concept of 'rescue archaeology' was yet to be conceived of at the time of the surveys (Potter 1979: 3-9; Patterson and Millett 1998: 3-4).

The huge material collections of the South Etruria surveys – including ceramics, glass, building materials, and marble – were supplemented by excavation in some areas in order to create dated sequences for most periods. This enabled interpretation (and subsequent re-interpretation) of the collected survey material. One of the most important studies was that of the African Red Slip ware by John Hayes (1972). However, despite the addition of many new sequences, there were and are, long periods for which we know little of the pottery chronology. The late antique and early medieval periods are particularly problematic in this respect, and are only now being re-evaluated in the light of new study (Patterson and Millett 1998: 11). The long periods of use for certain ceramic types – sometimes hundreds of years – means that it is often impossible to tell if certain sites were occupied contemporaneously or not. This means that we may overestimate the number of sites in occupation at the same time. Additionally, the absence of pottery does not necessarily mean an absence of a site (Sbonias 1999: 5-6; Potter 1979: 12). It is therefore likely that the data we have represents only a fraction of the Roman sites in this area, with settlement density likely to have been higher than the archaeological evidence suggests. This can, however, be incorporated into our models using randomly sampled data (see Chapter 8.4).

Within the original surveys, a simple ranking scheme of 'villas', 'farms' and 'huts' was established in the area to categorise the size of rural sites, mostly based on scatter size and building materials present. However, Potter himself does admit that this type of distinction was subject to wide margins of error, and the use of three broad classifications gave very general patterns of settlement dynamics (Potter 1979: 12). However, it is the chronology of these sites that is the major change between the original survey and the recent re-evaluation of the material. The original dating of the material was less precise at the time of Potter's synthesis, with many pottery types covering time periods of several centuries. The data from the original study has since been reassessed in the light of new pottery dating sequences (Patterson *et al.* 2000). This ranking scheme is therefore investigated further in Chapter 3, in order to reassess whether these divisions remain appropriate.

Across the river, in the Sabina, there is significantly less data from field surveys (see Figure 2.8). The surveys almost entirely neglected this area, and the most important contributions come from John Moreland's Farfa survey (1987) which was mainly geared towards the study of late antique and early medieval settlement. Additional work was carried out in the Eretum area by Ogilvie (1965) and by the survey of Cures Sabini for the *Forma Italiae* series (Muzzioli 1980). Recently however, the British School at Rome have resurveyed the area of Cures Sabini (Di Giuseppe *et al.* 2002) as well as the area of Galatina (unpublished). The surveyed Sabine areas are topographically similar to South Etruria, being the flatter parts of the region, but the Sabina has a diverse landscape and many of the more mountainous areas in the pre-Apennines have not been investigated. These types of areas could yield very different settlement patterns were they to be studied.

All field survey data has been integrated with digital geographical data, as well as information from other fieldwork projects in the study area. The aim of this is to provide an understanding of the development of settlement in the area, and rewrite the landscape history of this historically important region (Patterson *et al.* 2000). The sheer variety of settlement in the study area, however, precludes the possibility of producing a general settlement model for the whole of Italy. However, it will be possible to assess likely regional patterns and differences in production potential for different parts of the study area.

Regional research programs are becoming increasingly common, and field survey is a major part of such studies, particularly in the Mediterranean (see Figure 2.9 above, and Alcock and Cherry 2004). As such, they have generated vast amounts of information regarding the settlement dynamics of the "*less important*" sites (Yntema 2002: 1). Techniques are constantly improving, yet there are still many known issues with using survey data, and this has been explored in detail by Cherry in a seminal article on methodological issues (Cherry 1983) as well as more recently in a volume on comparative survey (Alcock and Cherry 2004).

Firstly there is the problem of site classification. Though Potter ranked the sites from South Etruria into three classes (see above) this was essentially an arbitrary process, based on qualitative assessment of the materials recovered and, as pointed out by Ikeguchi (1999/2000: 8), is problematic when considering those sites on the borders of categories. As regards human error and differences between surveys, there are factors such as the collection strategy of each survey and its intensity, the visibility of the ground walked, and the definition of what density of sherds equates to which kind of site. There are collection issues also, such as the tendency for fieldwalkers to pick out brighter finewares, rather than dull coarsewares, which could affect the discovery of lower status farms with less material culture. Similarly, different fieldwalkers attach differing significance to found objects such that some may be left in the field, deemed unimportant (Sbonias 1999: 2; Potter 1979: 12; Thompson, discussion in van Leusen 2002: 129).

There are also problems caused by natural factors and post-depositional processes. Sites from earlier periods often have a smaller number of sherds due to destruction and erosion caused by later settlements: in the South Etruria survey, for example, prehistoric settlement was often obliterated by later Roman agricultural activity. Also, higher status sites are often easier to identify than smaller, lower status sites, due to generally more visible architectural remains and luxury goods (Witcher, discussion in van Leusen 2002: 128). Sites located in river valleys are also more likely to be overlooked due to their disappearance under layers of alluviation; often they are only found in areas where the alluvial deposits have eroded, with examples including the viaduct across the River Treia near Civita Castellana (Brown and Ellis 1995) and the Valchetta bathhouse near Veii (Jones 1960). Movement of finds after their initial deposition also occurs frequently with surface scatters. Agricultural activity, erosion, and climatic factors can all play a role in the movement of ancient material (Taylor 2000).

Recovery rates for field survey have also been variously estimated, and this factor is of key importance to this study. Bintliff and Snodgrass (1985: 143) estimated a recovery rate of 57% for the field survey of Boeotia. This was based on the textual sources for demography and as such have been seen as problematic (e.g. Terrenato 2004: 44). For Italy, particularly the Albegna Valley, a 20-33% recovery rate has been estimated based on the discrepancy between Late Republican surveyed sites and the number of colonists known from the sources (Cambi 1999: 121).

All of these factors and more contribute to potential problems within the dataset. However, the sample under scrutiny here is sufficiently large to minimise the effects of such factors (see also Potter 1979: 12). This theory is supported by Patterson who argued that the unique nature of the South Etruria surveys, occurring in areas newly under plough, was more likely to record the smaller, less archaeologically visible sites than more recent surveys in areas under long-term cultivation (J. Patterson 2004: 65).

Furthermore, the potential archaeological value of the data is great, and provides the opportunity to investigate theories of settlement and production. Field survey results can raise issues not only about why people lived in certain places, but also why they avoided others, and are therefore a very important tool for landscape archaeologists (Yntema 2002: 2). Survey data enables the generation of settlement distributions: the location of sites and their interpretation based on the material recovered is usually one of the fundamental aims of this type of survey. The implications for demographic studies are therefore profound. These data may be used in various ways, for example, to estimate the size of sites, their density, their proximity to centres and resources, and therefore estimate the population size of a given region. It is possible to ascribe relative population figures to each site based on ethnographic evidence in order to estimate a general population for the whole area, although this has its own problems. It may also be possible to detect long-term changes in populations, as well as spatial differences in population and settlement trends (Sbonias 1999: 1-2). The potential low recovery rate discussed briefly above is consequently problematic when using such results for demographic purposes. This study therefore approaches the issue in a slightly different way, modelling both recovered sites and sample sites to gauge the effects on production and population (Chapter 8).

2.2.5 Farm location and desirable resources

Criteria for choosing the location of estates is intrinsically linked to the natural landscape and productive potential, as well as being connected with what were considered to have been valuable resources in this period. As well as discovering the location of rural sites through field survey, we have additional evidence to investigate this further. The types of land recommended for estate location (rather than smaller-scale units) were discussed in the works of the agronomists, and the criteria used will be discussed further in Chapter 4, as this is connected with the main focus of this study. The location chosen could also depend on the function of the villa. Many country residences were just that – country residences – rather than agricultural production units. Some villas, such as Settefinestre in Northern Etruria, undoubtedly operated as both (Carandini 1985), but one might imagine that the resources desirable for agriculture would have been inherently different to those conducive to a relaxing atmosphere and country retreat. Purcell (1995: 159), however, stated that many villas were located in order to "*command views, not of distant hills, but of the fertile terrain which belongs to the estate*" implying that a view of the productive landscape was highly desirable. He based this on evidence from Pliny (*Ep*. 5.6), Cicero (*Fam*. 7.1.1) and Martial (4.64) who described the views from their own estates and "*the* spectaciuncula *of people going about* *their ordinary activities*" (Purcell 1995: 159). Varro (*Rust*. 1.6.1) also refers to two different types of landscape – one natural and one created by cultivation:

> *…there are two kinds of conformation, the natural and that which is added by cultivation, in the former case one piece being naturally good , another naturally bad, and in the latter case one being well-tilled, another badly.*

Spurr (1986a: 22) argued that this ordered, man-made landscape produced profit and appealed to their aesthetic sense.

Communication routes, as mentioned by Cato (*de Agr*. 1.2-4), seem to have been attractors for settlement. The laying out of the major consular roads from Rome, for example, is known from field survey to have impacted on the pattern of settlement in South Etruria. New settlements grew up along the routes of these roads. As well as creating new centres, this process also meant that inaccessible towns became backwaters. Veii, for instance, was once a prosperous Etruscan centre, but was seen to diminish in importance when it was overlooked by the new consular road network (Ward-Perkins 1962: 397-398).

The most important aid to agricultural intensification was the control of water – both in ancient times and modern – and so, according to Purcell (1995: 171), it is necessary to view the villa or farm as being set within a hydraulic landscape, given its role as a focus of water-management. Research in the region of Lazio has demonstrated the widespread use of water-control systems on both large and small agricultural units (Wilson 1994). The location of natural and man-made water sources is of the utmost importance for both domestic and agricultural use, and consequently it is to be investigated further whether it was a primary factor in the location of sites.

Another important factor in locating rural sites, according to the sources, was proximity to a town or market. Most rural sites tended to be situated reasonably close to these urban centres. Every Roman city had an associated *territorium* where the majority of the town's inhabitants resided, particularly the elite. It is their produce that is likely to have supported the sections of the urban population not engaged in agricultural activities (Dyson 1992: 122). Added to this is the idea that peasants, even under ideal conditions, would only have travelled short distances to markets (Chisholm 1973: 43-67, 111-136). This was probably due to the cost of transport and the time spent away from the farm, and so would have made it desirable for agricultural units to be situated near to market centres.

It was a luxury of the rich to be able to pick and choose which land they wanted to purchase. In contrast, many settlers in Italy obtained land through veteran allotments as colonies were formed across Italy (see particularly the *Corpus Agrimensorum* discussed in Chapter 3). It is unlikely that colonists would have had much choice in which area they were settled, particularly given the complex administration overseeing the division and allocation of land (Gargola 1995: chap. 8-9; in Campbell 2000: liv). Land pressure was often an issue, especially in the peak of settlement in the early Empire, and so the most desirable areas would no doubt have been very densely occupied. Even by the 50s BC, Cicero (*Leg. Agr.* 2.68) implied that quite a high rural population was present, and that good land was becoming scarce (Dyson 1992: 88). This issue is one hypothesis that may be tested by looking at any changes in distributions between the late Republican and early Imperial periods (see Chapter 4). However, an interesting addition to this idea is that variation in allotment size seems to have been controlled: as well as distinctions in allotment size according to rank, in some areas there was an attempt to allot veteran plots by land fertility, therefore, in theory, all veterans of similar rank would have received the same productive capacity (see Chapter 3). The possible presence of veteran allotments within the study area introduces problems for modelling given the nature of how land was allocated. However, the number of colonies situated within the study area are thought to be limited, given its proximity to the capital, and only a few areas have been identified as possible veteran plots (for example the smallholdings at Monte Forco in Section 2.2.3; Jones 1963: 147-158).

In summary, a number of resources were obviously important when choosing where to locate a rural site, as evidenced, for example by Cato (*de. Agr.* 1.2-4, discussed fully in Chapter 5). These included proximity to water sources, urban areas, and roads. Which of these resources was considered to be of greatest importance to the Roman farmers, however, is unknown. This is where a locational model of the known sites in relation to the textual sources is an important addition to our knowledge of Roman agrarian history. By determining which resources could be considered the most important, an insight may be gained into the varied economic strategies and why the sites in this area are located where they are. The available evidence is both abundant and diverse. The aim is therefore to collate this information in a quantifiable way. Each data source is naturally subject to its own limitations and biases, but the modelling method used offers a new means of testing these data and examining the implications for established theories of settlement and demography.

3 THE SIZE OF ROMAN AGRICULTURAL UNITS

3.1 Archaeological and textual evidence for farm and estate size

The first stage of this study is to investigate the possible exploitable areas of farms and villas in the region. This involves an assessment of all the available textual and archaeological evidence for farm and villa estate size, as well as an analysis of the known site distributions from the South Etruria surveys. Whether the picture implied by the textual evidence is similar to that from the archaeological data is of particular interest, and by comparing the two sources, it may also be possible to determine any bias in either dataset.

Although we have information regarding the nature of an estate's central villa or farm building (e.g. through excavation), it is very difficult to determine the size of the territory it controlled. Studies concerning the size of landholdings have tended to use both textual and archaeological evidence to determine the physical limits of estates. Textual studies include discussions of veteran allotments and alimentary inscriptions (for example Champlin 1981; Keppie 1983; Patterson 1987). Alternatively, estimations have been made based upon aspects such as storage capacity of excavated villas, manning ratios, and quantity of seed used (Berqvist 1992; Duncan-Jones 1982).

We know from a number of ancient sources that the size of agricultural units varied enormously during the Roman period. These units, however, have commonly been described in the modern literature using the conventions of 'large', 'medium' and 'small' (e.g. Potter 1979) – categories that embrace different things in different periods. For example, a large estate in the Early Republic would not appear so when compared with the huge estates of the later Empire, particularly Imperial holdings (e.g. Duncan-Jones 1976: 8). Furthermore, individual interpretation of what constitutes 'large' or 'small' is illustrated by the various descriptions of Cato's *vinea*: his 100 *iugera* (25ha) vineyard has been described variously as a "*large-scale industrial establishment*" (Sergeenko 1952), a "*medium-sized estate*" (Frank 1954: 237); and a "*small farm*" (Hug 1953: 1216ff; all in White 1967: 63). Even now, with the proliferation of field survey, comparison of site definition is difficult due to the differing nature of regional settlement. What may be considered a rich villa in one area may be classified as 'medium-sized' in another (Alcock and Cherry 2004).

As discussed previously, each type of evidence used in this study has its own limitations and problems of interpretation. Texts are perhaps the most problematic of all, with issues such as the possible agenda or social bias of the writer in question, and whether the account was written contemporarily or based on earlier sources (see Chapter 2). Archaeological evidence can also be problematic. Actual boundaries of estates cannot be identified on the ground: although numerous boundary stones exist, they are rarely found *in situ*. The use of aerial photography in identifying the division of land from centuriation also may not be indicative of estate boundaries, as these plots would frequently have been subdivided, as demonstrated by Roman cadastral inscriptions (Section 3.1.2).

In order to assess and compare the different sizes of landholding, various ancient textual and archaeological data were entered into a database in order to determine if there were any visible patterns in size, space or time. References to landholding from beyond the geographical scope of this study have been included in order to gain insight into the changes in estate size across the peninsula, as well as sources utilising literary conventions such as the

Cinncinnatus example, and other moralising rhetoric. These types of evidence will not necessarily define the *actual* size of agricultural unit in this period, but will go some way towards our understanding of what was considered large or small at the time.

3.1.1 Evidence for villa estate size

Evidence for pre- and early Roman estate size is restricted to textual sources of dubious relevance. A controversial legislation for the distribution of public land, the *Lex Licinia Sextia*, was passed by the tribunes Gaius Licinius and Lucius Sextus in 367 BC. Details of the exact nature of this law are sketchy, although it is mentioned in various ancient sources (Livy 6.35; Columella *Rust*. 1.3; Pliny *NH* 18; Varro *Rust*. 1.2; Appian *B Civ*. 1.8). According to these sources, seven *iugera* were distributed to each citizen and, most controversially, the law restricted the amount of *ager Publicus* (land belonging to the Roman state) that could be utilised by an individual. No more than 500 *iugera* (125ha) were to be cultivated, or no more than 100 large or 500 small animals were to be pastured on this land. This is claimed to have contributed to the growth of the peasantry by limiting the elite's ability to increase landholdings beyond this level (Rostovtzeff 1957: 13), but this applied only to public land and not any private holdings a family owned. By imposing such a boundary, it may be argued that estates at this time were beginning to grow beyond such limits, thereby contributing towards the traditional view of the Roman countryside as characterised by large estates. 500 *iugera* (125ha) and above can be considered a large estate, far beyond the level a regular citizen or veteran soldier would have been able to cultivate. Columella argued that 200 *iugera* can be cultivated with six men (Rust. 2.12.1-6), therefore it follows that one man can cultivate around 33 *iugera* (see Chapter 7 for more on manpower and workload).

The 2nd century BC was a period characterised by upheaval and agrarian discontent. As discussed above, the traditional view is one of the rapid decline of the smallholder after the Hannibalic wars. Land was a controversial issue, particularly regarding the use of *ager publicus*, and Tiberius Gracchus' attempts to dispossess the elite occupiers of public land in favour of landless Roman citizens in order to boost Rome's military power led to political conflict and ultimately his death (Toynbee 1965: 190-193).

The passages from Plutarch (*Ti. Gracch.* 8-9) and Appian (*B Civ* 1.7-11), on which this traditional view is based, provide only a vague view of the general size of holdings. However, later laws and sources provide some information on plot sizes. The *lex agraria* passed by Tiberius Gracchus required all public property held in excess of the *lex Liciniae-Sextiae* (500 *iugera*), to be requisitioned and redistributed in smaller allotments to citizens, for which they would pay a small rent. Meanwhile, the 500 *iugera* retained by the large landowners would officially become their property (as well as any private land they may have already held). We cannot, however, gain much insight into the specific sizes of holdings from these laws. Evidence of limits, though indicating the presence of landholdings of a large size, does not enlighten us as to the size of smaller landholdings that must also have co-existed.

The earliest literary source explicitly regarding estate size is from Cato. His treatise on agriculture gives detail regarding the ideal equipment for both a 240 *iugera* olive plantation (*de Agr.* 10) and a 100 *iugera* vineyard (*de Agr.* 11). This has been used to argue the case for early agglomeration of land into *latifundia* (Sergeenko 1952; in White 1967: 63) however, Hopkins (1978: 105, n.13) pointed out that the units spoken of by the agronomists were merely formal models rather than actual landholdings: they were used to illustrate the equipment needed for such a plot, and this could then be adapted to whatever size holding one actually farmed, whether larger or smaller. Varro also discussed whether Cato's models were indeed intended for this purpose (*Rust*. 1.17.3-5), and even argues that 240 *iugera* was not a standard unit of measurement, using centuriation as the yardstick. Why this particular estate size was chosen is therefore unknown, although it is feasible that it could be interpreted as a reflection of a real estate configuration. These sizes (100 and 240 *iugera*) are not unfeasible as general landholdings, with other references and archaeological evidence attesting to similarly sized agricultural units. For example, cavalrymen are described as having received allotments of 140 *iugera* at Aquileia (Livy 40.34.2f), whilst some landowners from the Veronese cadastre held similar-sized estates (Section 3.1.2).

There are some sources, however, that inadvertently provide information regarding the variety of estate sizes in antiquity. Within the study area are a number of ancient references illustrating this. References to specific landholdings include two different estates of 1,000 *iugera* (250ha) near Rome from the late Republic (Cicero *Att.* 13.31; Varro *Rust*. 2.3.10). C. Albanius bought the former estate for *HS* 11,500,000 but the passage does not indicate what type of economy it followed (e.g. arable or pasture). The latter was probably a suburban villa estate owned by a citizen called Gaberius and it is thought to have had a pastoral economy. Varro (*Rust*. 3.2.15) wrote of a 200 *iugera* estate at Reate (Rieti, just outside the study area in the Sabina) belonging to the senator Q. Axius, whilst Pliny the Elder (*NH* 14.5.48-49) wrote about one of the vineyards at Nomentum (within the study area). This vineyard was owned by Acilius Sthenelus in the Neronian period and was 60 *iugera* in size. Literary references from elsewhere in Italy include a poem by Horace (*Epod*. 4), in which the protagonist is said to plough "*a thousand* iugera *of Falernian ground*". Duncan-Jones (1982: 324) identified this area with Falerii, within the study area, but it is more likely to refer to the region in northern Campania from which Falernian wine came, south of the study area. This would fit with the tone of the poem, as this area was renowned for fertile ground, particularly good for vines.

The estate sizes documented in these references have been varied. This may be due partly to literary licence, but may reflect also the different economies being described. Vineyards tend to be cultivated in smaller plots than cereal crops (e.g. Cato's model vineyard of 100 *iugera*, above). 1,000 *iugera*, however, is a very large plot to cultivate, even with cereals, and would appear to highlight the satirical nature of Horace's poem.

Using literary sources in this fashion is liable to criticism. We do not know the authors' reasons for discussing estates, and some may have played the size of estates up or down. For example, in the Epode of Horace mentioned above it is implied that a farm of 1,000 *iugera* is a large area for someone as lowly as a freedman to be farming. 1,000 *iugera* (250ha) is indeed a very large plot when compared with the veteran allotments, but then examples of extremely wealthy freedmen are not unheard of in the ancient sources either (see for example Isidorus, Section 3.1.3).

On the other hand, Pliny the Younger downplayed the size and opulence of his estates. In his descriptions of these (Ep. 2.17, 5.6) he largely omitted descriptions of interior decoration, and is argued to have thus portrayed himself as a "*gentleman farmer*", having described his Laurentinum property diminutively as a *villula* rather than *villa* (Bergmann 1995: 409). These agenda, which colour the literary evidence, do lead us away from a precise knowledge of the size of estates, but nonetheless provide an estimate of what size of agricultural unit was considered large or small in this period. The following sections, however, compare this type of textual evidence to archaeological data from the study area and enables comparison.

3.1.2 Evidence for smaller agricultural units

Evidence for smaller units tends to come from archaeological data rather than textual, though some examples do exist in the sources. According to Varro (*Rust.* 1.10.12), the first Roman agrarian law, made by Romulus, allotted two *iugera* (approximately half a hectare) of land to citizens as their *heredium*. This was thought to be enough land on which a family could subsist. Mommsen (1868: 205-206), however, argued that the two *iugera* merely applied to garden ground, and that the *gens* or *familia* held most land jointly. This was based on the remark by Pliny the Elder (*NH* 18.7) that the term '*heredium'* in early Rome was used in the sense of '*hortus'* (garden). According to Livy (8.21.11), two *iugera* were also distributed to colonists at Terracina in 329 BC, and this is backed up by archaeological evidence from centuriation grids (Campbell 2000: 389, n.18).

Livy (5.30.8) and Diodorus (14.102.5) also refer to allotments of either four or seven *iugera* (1 or 1.75ha) of Veiian territory redistributed to plebeian settlers earlier in 393 BC. This was seen as a generous allotment as the allotment was said to have been made, not just to heads of families, but to all plebeians. Similar figures of seven or eight *iugera* (1.75-2ha) were discussed by White as minimum subsistence plots, but these are small and it has been suggested that they would have been supplemented by foraging, the use of *ager Publicus*, or by carrying out occasional waged labour (White 1970a: 336, based on unpublished work by K. Hopkins).

One of the most useful sources for determining the nature of non-elite agricultural units is the *Corpus Agrimensorum*, the collected works of the Roman land surveyors (Campbell 2000). The *Corpus* was probably compiled in the 5th century AD from earlier sources, with subsequent additions in later periods. It contains very useful pieces of evidence such as the *Libri coloniarum* (two lists of colonies in Italy and Dalmatia), and the *Casae litterarum* (four lists of country estates under the late Empire). The manuscripts themselves are sometimes fragmentary and the authorship of certain works cannot be verified, and they may not always reflect the situation at the original time of writing due to the long period over which they were compiled (Campbell 2000: chap. 3). However, they cover important topics such as colonial settlements and the farms allotted to veterans, and provide a broader picture of the nature of landholding in the Roman period than that of other textual sources. Evidence from the *Casae Litterarum* also shows examples of model estates, thought to have been for the instruction of land surveyors. These illustrated the types of landholding a surveyor could expect to come across during the course of their work (Campbell 2000: 227ff; Dilke 1967; White 1970a: 33), and as such, they complement the other literary and epigraphic evidence.

Land surveying has a long history within Roman society, beginning in the Early Republic with the foundation of the Latin colonies as a direct result of Rome's expansionist activities. It has been estimated that up to 350,000 people were resettled between 59 and 14 BC. Land settlements were highly political subjects, and this is evident from ancient sources (Campbell 2000: liv; Brunt 1971a: 255-9). Land settlement schemes were not always welcomed. In order to make room for the incoming colonists, the native inhabitants of an area were very likely to have been displaced and their lands confiscated. Horace suffered as his estate at

Venusia was confiscated (*Ep*. 2.2.50-51), and Virgil (*Eclogues* 1.71-3) also experienced confiscations of land.

> *Is some blaspheming soldier to own these acres I have tilled so well,*
> *Is an outsider to reap these fields of corn? Look at the pitch of misery to which civil war*
> *Has brought Roman citizens.*
> *To think that we sowed our fields for men like this to reap!"*

Virgil was speaking from personal experience, as the lands of his home city of Mantua were confiscated, although he ultimately retained control of his property. It is possible, however that only medium-sized properties were at particular risk, given the poorer quality of smaller properties, and the likelihood of protection for richer ones (Dyson 1992: 91-92).

Not all the effects of such settlements would have been negative, however. The new smallholders were not necessarily inexperienced farmers. Many veterans were likely to have originally come from rural areas, and it is these smallholders who served as a base for the prosperous communities of the Early Imperial period (Dyson 1992: 91-92; Brunt 1962: 73-74). This argument is strengthened by Keppie (1983: 123), who argued that the eagerness with which veterans sought and tried to retain land indicated that they wanted to farm and develop their allotments, particularly as it offered them the opportunity for social improvement.

Horace also described the displacement of a peasant farmer, where the farmer's land was allotted to a veteran settler. In this case, however, the original farmer remained on the land as a tenant and continued its cultivation (Dyson 1992: 92). This demonstrates continuity of cultivation in the landscape, despite lack of continuity of ownership. Whether or not this was typical, however, cannot be known.

> *…this Ofellus … used his full means on no larger scale than he does now, when they are cut down. You may see him on his little farm, now assigned to others, with his cattle and his sons, a sturdy tenant-farmer*
>
> Horace *Sat*. 2.2.112-115

Veteran allotment schemes occurred throughout the Roman period, with major schemes carried out by, amongst others, Caesar and Augustus. The *Libri Coloniarum* provide the names of a colony's original founders, ranging from the Gracchi and Sulla up to the late 2nd century AD. Cicero (*Ad Fam*. 9.17.2) mentions the Caesarian settlement scheme carried out in the *ager Capenas* in 46 BC – it has been asserted that the series of small farms on the Monte Forco ridge (discussed in Chapter 2) have been identified as possibly being part of the Caesarian allotments of 46 BC (Jones 1963: 32). According to Potter (1979: 113, 142), however, it was the Augustan settlement which had the greatest impact in South Etruria. The Augustan settlements as a whole had a great impact on the landscape of Italy, reorganising the peninsula into regions and founding many new colonies.

The amount of land allotted depended on many factors, including military rank as well as fertility of the land. Evidence from the *Libri Coloniarum* in the *Corpus Agrimensorum* shows that the higher in rank a veteran was, the more land he would tend to have been allotted (e.g. at Volterra, *Lib. Col.* 169.23-26). Also, it is stated that there were larger allowances for poorer quality land (Siculus Flaccus *De Condic. Agr*. 123.30-32). Although compiled in the 5th century AD, the *Libri* contain references to allotments made from the Gracchan period onwards (Campbell 2000: xx; Dilke 1992: 126, 227; White 1970a: 33).

There was consequently no 'normal' allotment size, as the evidence indicates their being anything between 5 and 50 or 51.5 *iugera* (Brunt 1975: 623). However, all evidence from this source has been included in the database, including those references to centuriation. The division of the landscape into regular grids of approximately 200 *iugera* (*centuriae*) was commonplace in the Roman period, although not prolific within the area of study. These too have been entered into the database, despite the fact that they would often be subdivided into smaller plots. The fact that they are centuriated plots rather than actual holdings, however, has been noted.

Archaeological evidence relating to centuriated plots includes cadastral maps known from the Roman period. Until recently, none were known from Italy itself. The most famous examples are the fragments of the 1st century AD cadastres from *Arausio* (modern Orange) in France. Cadastres were the records of surveys carried out for taxation purposes: each square inscribed relates to one *centuria*, usually 200 *iugera* (approximately 50ha), although *centuriae* of different sizes are known. There is variation even within the Orange cadastres themselves, with *centuriae* of between 200 and 330 *iugera*. Each inscribed square contained its location in relation to the *decumanus maximus* and *kardo maximus* (the main axes of the centuriation), the status of the land, the tariff and total rent payable, and details of rents. The maps also included topographical features such as rivers and streams, islands and other roads not aligned with the centuriation (Dilke 1998: 108-109).

In 1996, archaeological investigation uncovered a cadastre from an area in northern Italy. An inscribed bronze rural cadastre, probably of the second half of the 1st century BC, was discovered during an excavation of a section of the Capitoline cryptoporticus of Verona (Cavalieri Manasse 2000: 5, 44). This is a rare find in Italy, and differs from other cadastral documents discovered previously. The cadastre is fragmentary, consisting of a row of empty plots (the *decumanus*), and underneath, three plots of a centuriated landscape. Figure 3.1 shows the fragment itself and the hypothetical reconstruction of the whole cadastre.

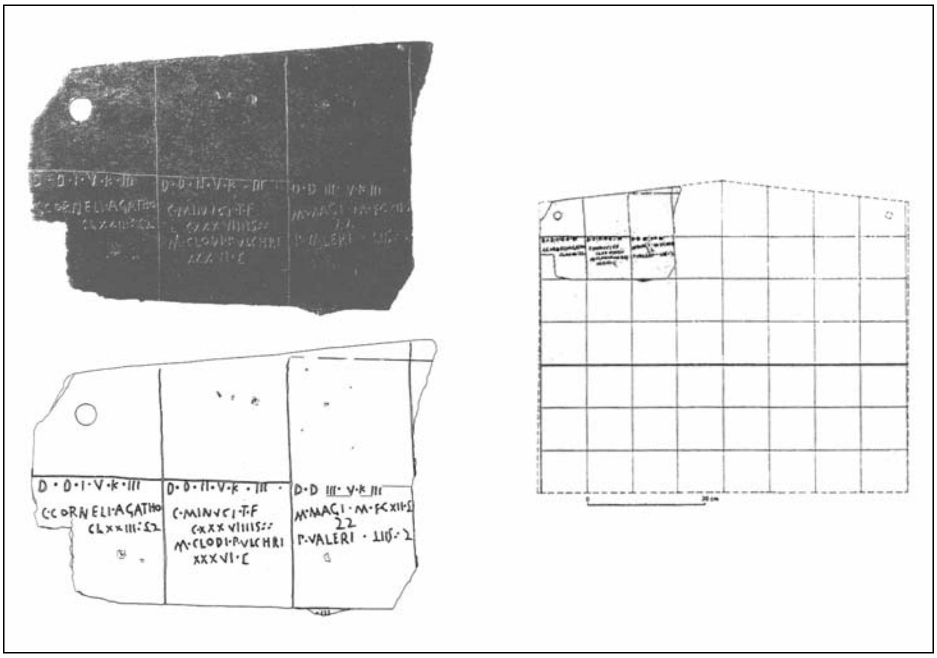


Figure 3.1 Fragment of the Veronese cadastre and reconstruction of the entire table (drawings by S. Bombieri in Cavaliere Manasse 2000, tav. I-II, p.49-50)

The plots varied in size from 36 up to 173 *iugera* (9-43ha) (Cavalieri Manasse 2000: 6-7) and demonstrate the existence of the medium-large sized plots that are almost non-existent in the literary sources. Rather than showing the allotment of surveyed land according to strict measurements, the irregularity of these units has been interpreted as the quantification of pre-existing properties in the Transpadana within a centuriated framework (Cavalieri Manasse 2000: 26).

3.1.3 Deriving plot sizes from other evidence

There have been a number of attempts to derive plot sizes from a variety of archaeological and historical evidence, some more credible than others. These are discussed below. Clearly, any attempt to derive estate sizes from indirect evidence is a hypothetical exercise, though it may still provide insights into the nature of Roman landholding.

Cicero, in his speeches against Verres, who was then in his first year as governor of Sicily (73 BC), discussed the number of farmers in the area of Leontini, as well as the area of land under wheat cultivation. In his first year as governor there were 84 farmers registered, a number which had fallen to 32 by the third year. In this year, 30,000 *iugera* were under wheat (Cicero *Verr*. 2.3.113, 116, 120). As the Romans usually followed a system of fallowing, Duncan-Jones (1976: 13) calculated that the area cultivated was over 60,000 *iugera* which, adding 10,000 *iugera* for other field crops, meant a mean holding of just under 2,200 *iugera*, or 550ha, per estate. Had the number of farmers remained at 84, the mean holding would still have been in the region of 830 *iugera*, or 207.5 hectares each (Duncan-Jones 1976: 13). Leontini, however, was the prime wheat-growing region in Sicily, and is unlikely to be representative of estate sizes in Central Italy in this period. Also, given that our main source of evidence is a speech speaking against the Sicilian governor, it may be that the figures disguise the true picture.

Duncan-Jones also investigated property sizes at Herbita in Sicily, again based on data from Cicero (*Verr*. 2.3.75-80). He argued that the corn tithe sold by the governor Verres for 18,000 *modii* in 73 BC implied a total area of cultivable land of approximately 14,000 *iugera* (35.2km^2), using the agronomists' five *modii* per *iugerum* sowing ratio (see Chapter 6). Between the 252 farmers listed, this meant an average holding of 56 *iugera* (14ha), which is highly comparable to some of the larger veteran allotments (Duncan-Jones 1976: 14)

Duncan-Jones (1976: 11) also used later evidence from the Theodosian Code (7.20.3) to attempt to reconstruct the size of plots. It was stated that Late Imperial veterans under Constantine received a yoke of oxen and 100 *modii* of seed, as well as expenses, and he assumed that 100 *modii* of seed meant that 50 *iugera* (12.6ha) were under cultivation, assuming fallowing.

The following examples demonstrate the sheer enormity of some estates in the Roman period. There has been some dispute over how much land was promised to his veterans by Domitius Ahenobarbus during the war between Caesar and Pompey. It is generally believed that the original text of Caesar's *Bellum Civile* (1.17.3) should read that he pledged XV rather than XL *iugera* of his own land to veterans in the event of his victory over Caesar, as 40 *iugera* per veteran would have been an incredibly large amount of one's own land to pledge to each veteran, depleting his estate tremendously (Brunt 1975: 619). However, looking at the manpower that Domitius summoned from his estates we see that he manned seven *naues actuariae* with slaves, freedmen and *coloni* from his estates in Etruria, and later provided *coloni* and herdsmen for a Massilian fleet (Caesar *B Civ*. 1.17.3; 1.34.56; *CIL* I 1995; Suet. *Nero* 5.2; Cass. Dio. XLI 11.2). Brunt (1975: 620-621) therefore accepted the figure of 40 *iugera*, and estimated his total estate to have been around 400,000 *iugera* (100,000 hectares). He used this figure to illustrate the size of *latifundia* in this period in an earlier study (Brunt 1971b: 34). However, this figure is likely to refer to a collection of dispersed landholdings, mostly farmed by tenants, rather than one huge agglomerated estate.

Using a different method, Brunt (1975: 624-628) discussed the estate of the immensely wealthy freedman Gaius Caecilius Isidorus described by Pliny the Elder (*NH* 33.134f). He used Columella's calculations to estimate the size of his estate from the numbers of cattle and other animals. According to Pliny, despite losses from the civil war, Isidorus' will left 4,116 slaves, 3,600 pairs of oxen, 257,000 head of other cattle, and 60 million *sesterces*. With this data, Brunt reached estimates of landholding of about the same level as his calculations for Domitius Ahenobarbus – around 400,000 *iugera* (100,000ha). From the head of cattle alone, he had previously used the estimate that one head of cattle can plough 100 *iugera*, and so 3,600 head of cattle could plough 360,000 *iugera* (Brunt 1971b: 34). What must be remembered, however, is that such enormous estates were not likely to have consisted of one unit devoted to monoculture.

Large estates were frequently divided into smaller parcels for more effective exploitation, and worked by tenant farmers (e.g. Pliny the Younger *Ep*. 3.19; 9.37). The estate may also not have been one agglomerated unit, comprising instead a number of scattered parcels with a variety of topographies and micro-climates. Sextus Roscius, a client of Cicero (*pro Rosc. Amer*. 18-20), owned thirteen farms adjoining the Tiber, at Ameria north of our study area. These were valued at *HS* 6,000,000 in total (Duncan-Jones 1976: 12). Catullus (114-115) also described the agricultural holdings of Mentula in the territory of Firmum in Picenum. These lands were fragmented in order to take advantage of diverse resources, and were situated to utilise agricultural, pastoral, marine and woodland resources (Dyson 1992: 78).

Using archaeological evidence, scholars have attempted reconstructions of estate size from excavated evidence from the central villa. As far back as the 1930s an estimation of this kind was attempted for the Boscoreale estate near Pompeii (Day 1932). Day estimated the capacity of the *dolia*, and therefore the annual production, as 175 *cullei* of wine. Using a production figure of 3 *cullei* per *iugerum* led him to calculate that the vineyards would have been in the region of 58 *iugera*. Adding the land for producing necessary equipment (i.e. vine props) meant that the vineyard would have required 66 *iugera*. Adding production for 29 *cullei* of oil and other likely crops such as grain, led Day to estimate the size of the villa to be in the region of 100 *iugera* (1932: 183-184).

Berqvist (1992) later estimated the size of the Boscoreale estate, again using the storage capacity of the excavated villa. The Late Republican villa produced mainly wine, with oil as an additional product. The storage rooms contained 84 *dolia*, 72 of which had a liquid capacity of 172 *cullei* of wine. The remaining 12 contained grain and oil. Five *dolia* in the corridor contained olives. There was also an upper floor which was used partly for wine storage in amphorae, although the exact capacity of this was not discussed (Berqvist 1992: 116-17). Berqvist combined this evidence with that from the excavation of a large urban vineyard in Pompeii (Jashemski 1973) and contemporary statements on wine yields, to prove that the approximate size of the estate was at what he described as "*the lower end of the* villa rustica *category of the rich*" (Berqvist 1992: 115), although this was not quantified explicitly. Berqvist concluded ultimately that this technique was not particularly successful, as "*any fixed number of* iugera *cannot with certainty be attributed to the Boscoreale-villa*" (Berqvist 1992: 114-115, 137).

Duncan Jones stated that the sheer uncertainties of yield make it impossible to deduce farm sizes from wine storage capacities (Duncan-Jones 1976: 45, n.3). Indeed, given the fact that the particular cultivation strategy used, what percentage of the crop was stored, and other similar data, are unknown, such a technique is problematic. However, I believe that Duncan-

Jones and Berqvist are unduly negative. Though a *fixed* number of *iugera* may not be attributed, surely a *range* of potential sizes may be estimated using different variables?

3.1.4 Deriving plot size from value

In his agricultural treatise, Columella gave *HS* 1,000 per *iugerum* as a standard price for unimproved land (*Rust*. 3.3.8). This information, although with its own problems (Duncan-Jones 1982: 48-52; Carandini 1983: 190), may be used to derive estate or farm size from monetary values mentioned in sources. In this fashion, for example, P. Crassus Mucianus has been credited with land covering an area of 100,000 *iugera* due to his fortune of 10 million *denarii* (Nicolet 1994: 617, using information from Cicero *Rep*. 3.17). This, of course, assumes that his fortune was held entirely in land.

This technique has proved most informative, however, in the interpretation of the alimentary tablets from Veleia (*CIL* XI 1147), Ligures Baebiani (*CIL* IX 1455) and Volcei (*CIL* X 407). The utilisation of this epigraphic material has shed light on issues of property ownership as well as the size and distribution of smaller farms and estates in parts of Italy (Duncan-Jones 1982; Patterson 1987). These inscriptions were the manifestation of a welfare service (the *alimenta*) set up to provide subsistence for the children of poor citizens, and possibly with the aim of raising the birth rate (Bourne 1960; Duncan-Jones 1964; Rawson 2003: 59ff). It is not known for certain who implemented this scheme and it has been varyingly attributed to Nerva, Domitian and – most commonly – Trajan in the late 1st century AD. The *alimenta* was financed by means of Imperial grants to landowners payable at 5% interest annually, and the income generated by this was sufficient to support any local children in need (Bourne 1960: 47; Duncan-Jones 1982: 288, 291, 295; Rawson 2003: 252). There are a number of land registers from many parts of the Empire, for example North Africa and Asia Minor, many of which are related to alimentary programmes. Evidence of this kind from Italy itself, however, is relatively scarce, with tablets from Veleia (*CIL* XI 1147), Ligures Baebiani (*CIL* IX 1455) and Volcei (*CIL* X 407), being the only extant data of this type.

The alimentary tablets consist of a list of landowners and their pledged estates. These tablets do not give the sizes of estates specifically, but they do give their value and, in doing so, offer an insight into the distribution of wealth and the organisation of the landscape in these regions. They demonstrate a wide variety of estate values (and therefore sizes) during this period, which can be used to argue against the widespread proliferation of large agglomerated properties.

Champlin (1981) and Patterson (1987) discussed the attempts of De Pachtere (1920) to reconstruct the landscape and the property history of the region of Veleia in northern Italy based upon evidence from the tablets. Champlin (1981: 239), in particular, describes De Pachtere's work on Veleia as a "*masterpiece of historical topography*". By carrying out a close analysis of the names of owners and neighbours, De Pachtere succeeded in drawing up a map of *pagi*, and linked properties with location and altitude. The Veleian tablet lists forty-seven estates, but excludes total estates below the value of *HS* 50,000, although component parts may have been smaller. According to Duncan Jones (1976: 13), the average size of land parcels from the Veleia register varied very little, no matter how large the overall estate became. For example, the five largest estates had, on average, constituent parts of approximately *HS* 70,000, whilst the average for the smallest estates was just under *HS* 43,000 (see Table 3.1)

Table 3.1 Landholdings by Pagus from Veleia (after CIL 1147)

	Pagus I		Pagus II		Pagus III		Pagus IV	
	Hectares	*Iugera*	Hectares	*Iugera*	Hectares	*Iugera*	Hectares	*Iugera*
Total area	335.59	1342.36	593.74	2374.96	558.10	2232.40	419.94	1679.76
Minimum	12.75	51	12.50	50	18.99	75.96	12.59	50.36
Maximum	106.25	425	295.15	1180.60	253.52	1014.08	105.03	420.12
Average plot	47.94	191.77	74.22	296.87	139.52	558.10	52.49	209.97
	Pagus V		Pagus VI		Pagus VII			
	Hectares	*Iugera*	Hectares	*Iugera*	Hectares	*Iugera*		
Total area	574.71	2298.85	347.93	1391.72	209.75	839.00		
Minimum	12.50	50	13.48	53.92	7.50	30		
Maximum	289.53	1158.12	67.78	271.12	87.50	350		
Average plot	114.94	459.77	28.99	115.98	34.96	139.83		

Using Columella's statement that one *iugerum* of unimproved land was worth *HS* 1,000, these values were entered into the database. As this refers to unimproved land, it may be maintained that the figure calculated is an absolute maximum size for the plot, as worked land would have been valued higher per *iugerum*. Apart from this consideration, this data must be used carefully, as land prices were not a stable medium and were likely to have varied over time and area, regardless of land quality (see e.g. tax documents from Syria, *Leges Saeculares* 121, in White 1970a: 391). This could alter sizes of units significantly, although we may still be able to compare them qualitatively. Looking at each *pagus* we can see that each area had a good spread of plot sizes ranging from approximately 30 *iugera* (7.5ha) up to 1,181 *iugera* (400ha).

Veyne's work on the inscription from Ligures Baebiani (1957; 1958) was less successful than that of De Pachtere, although this had much to do with the more fragmentary nature of the tablet in question. He was able to shed light on the general topography of the region and the nature of the agricultural units, but unlike De Pachtere, was not able to create a map of the area from the evidence (Champlin 1981: 239). The tablet itself dates from the beginning of the 2nd century AD and contains a random sample of local properties of all sizes, although, as with the Veleia tablet, probably omits properties below a certain value. Also, nine of the 66 estate valuations are missing. However, the smallest property mentioned was *HS* 14,000, thereby giving us a reasonable cross-section of property sizes in the area (Duncan-Jones 1976: 16). Using the same method as for Veleia, the property sizes of Ligures Baebiani have been assessed.

Table 3.2 Landholding in Ligures Baebiani, (after CIL 1455)

	Hectares	Iugera
Total area	1117.8	4471.2
Minimum	3.5	14
Maximum	112.75	451
Average plot	15.65	62.59

The final land register from Italy is that from Volcei, in the south of the peninsula. It was compiled in AD 307, probably in connection with Diocletian's tax reforms, and outlines 36 farms and their tax liability. The register lists individual farms, but is unfortunately incomplete and as such cannot be reconstructed in such detail (Duncan-Jones 1976: 18).

Data from the alimentary registers, although depicting a wide variety of estates, have been considered still too selective to include the smallholder, and do not appear to include the same range of properties in each register. Also, it is possible that landlords owned property in other districts, meaning that total estate sizes could have been much larger than those illustrated in the registers. The three tablets have therefore been considered too localised to obtain basic regional estate types (Duncan-Jones 1976: 20-23). This data was, nevertheless, entered into the database created to compare evidence regarding estate size in the area of modern Italy. This variety is not problematic for this study, as we are merely collecting examples of different unit sizes to investigate the variety of recorded estate and farm sizes. All of the evidence discussed in the previous sections (3.1.1-3.1.4) is shown in Figures 3.2-3.4.

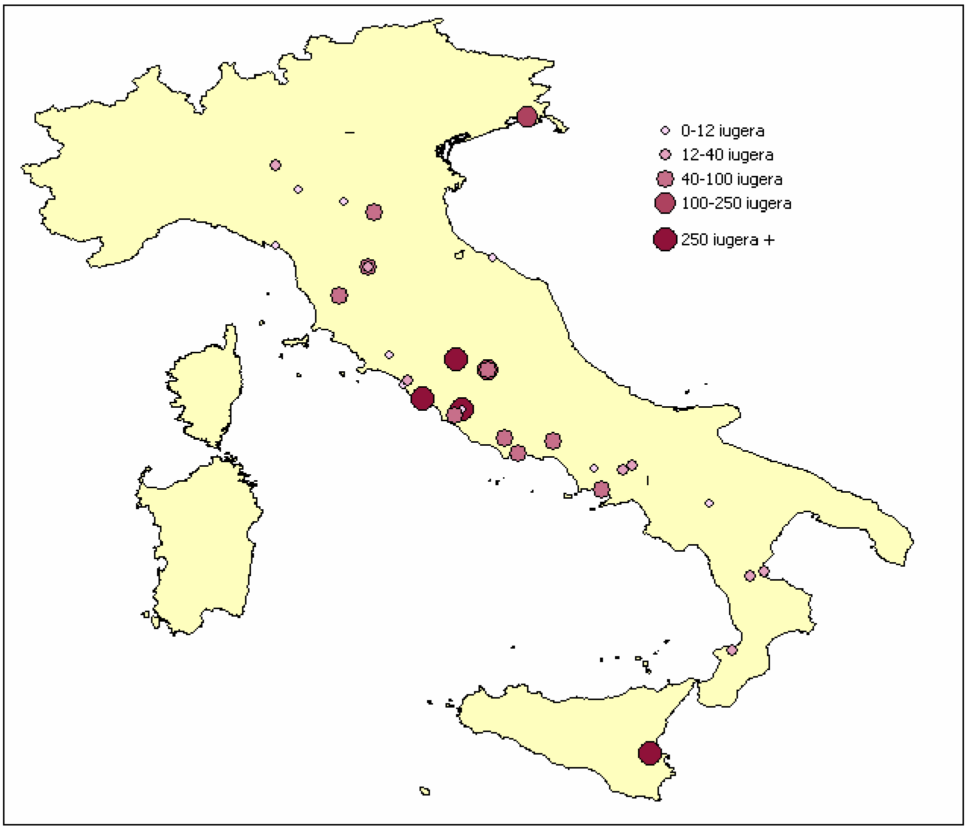


Figure 3.2 Land unit sizes (in iugera) from the sources (pre 30 BC).

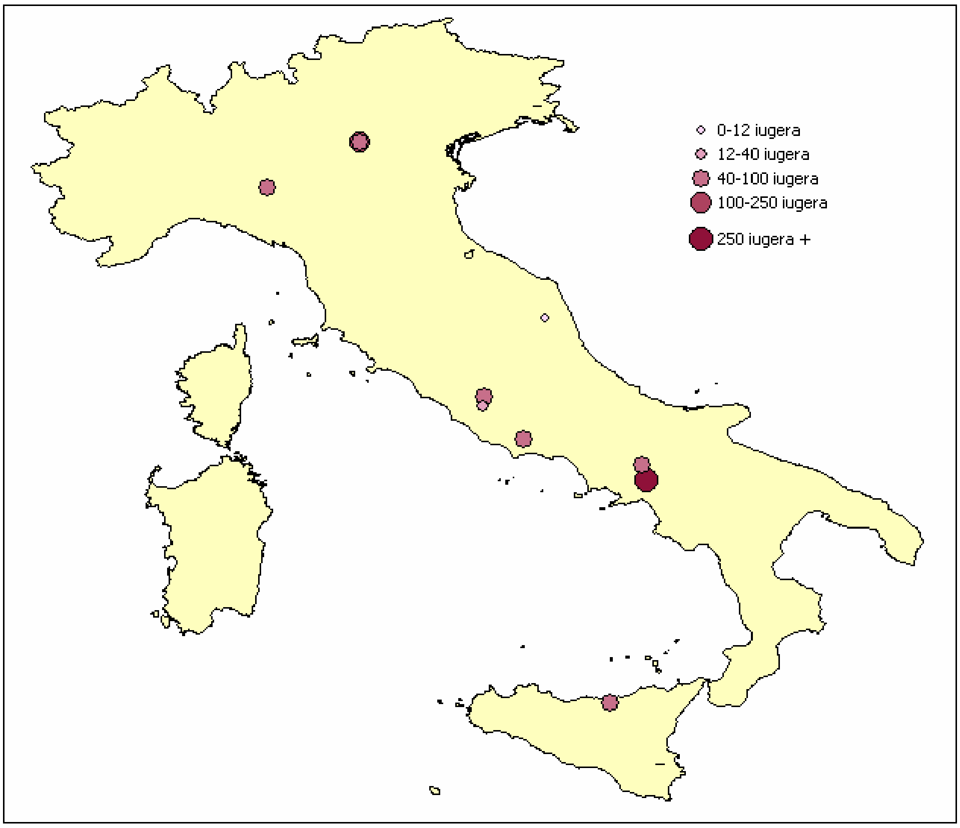


Figure 3.3 Land unit sizes (in iugera) from the sources (30 BC – AD 100).

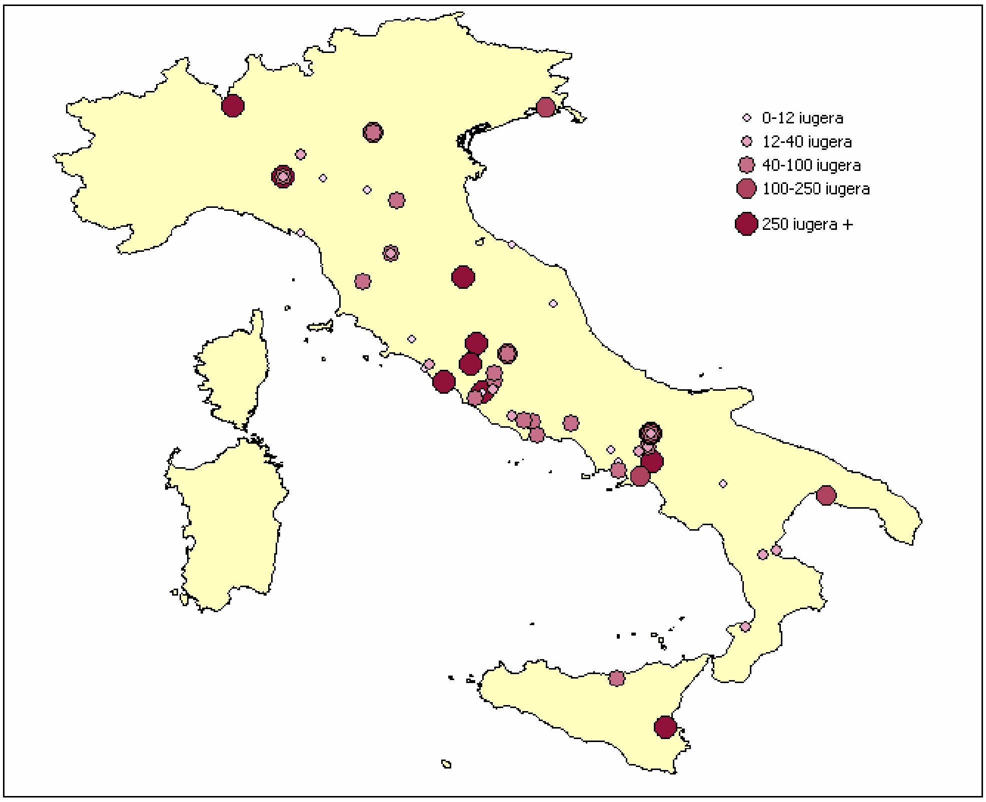


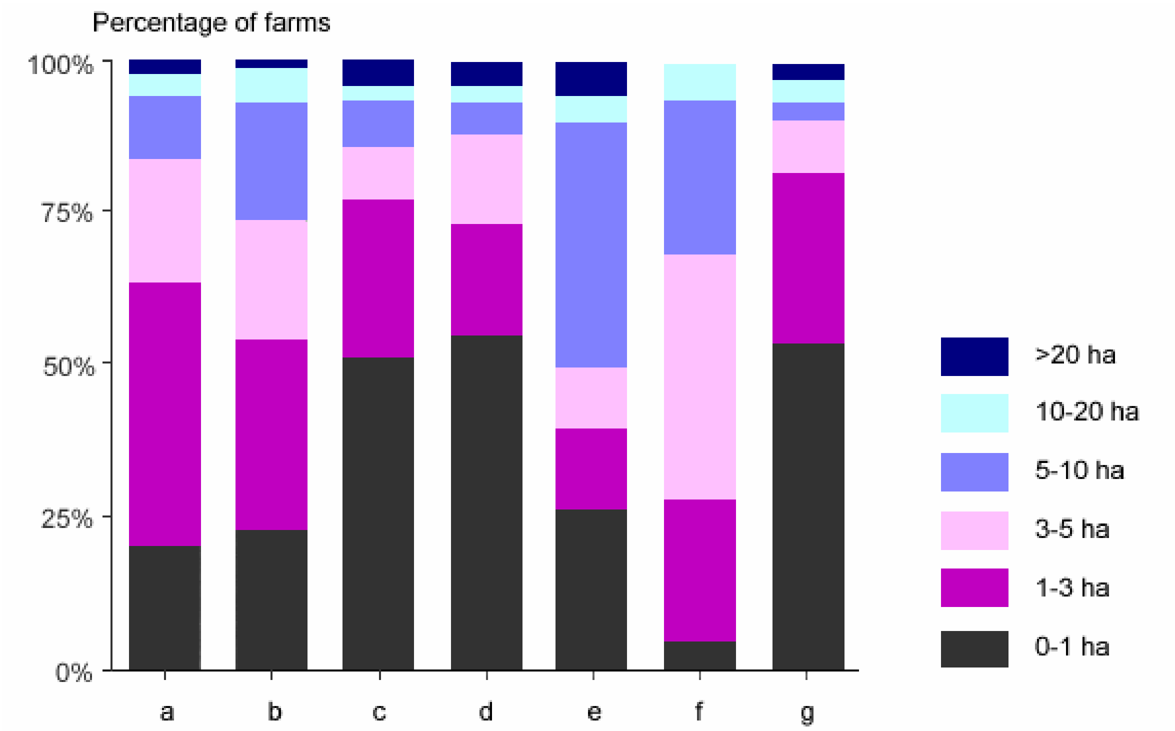
Figure 3.4 Land unit sizes (in iugera) from the sources (all periods)

3.1.5 Comparative evidence for peasant holdings

As there is apparently much data missing concerning medium-sized holdings, an alternative strategy for determining plot size is to look at how much land was required for minimum subsistence, and then determine how much land was required to provide enough for a household. Gallant, in his study of the ancient Greek peasant economy (1991: 82), investigated landholding in this way. Comparative data from contemporary peasant settlements led him to believe that minimum subsistence for a Greek household required a landholding of between 3.36 and 4.12ha. This equates to approximately 13.5 to 16.5 *iugera*, very similar to veteran allotments of the Late Republic and Early Imperial period. This was based on a number of studies from various countries, and so there will clearly have been some variety in production strategy, crops grown, fertility of the land and climate.

Some of the studies noted by Gallant (1991: 82-86) are as follows. Portuguese peasants believed that a plot of less than three hectares (12 *iugera*) should be considered small (O'Neill 1987: 76-77). Peasants interviewed from Southern Italy all had, on average, a 5ha plot (20 *iugera*) per household (Brögger 1971: 38), whilst Bengali peasants believed that between 2.5 and 3.25ha (10-13 *iugera*) was sufficient provided the plot contained some areas of high quality land (Bose 1986: 51). Hungarian peasants considered anybody with a landholding of between 2.8 and 5ha (11-20 *iugera*) to be a smallholder (Netting 1982: 644). Though these examples are not directly comparable to the Roman Italian situation, it is still interesting to note these differences in attitude.

Gallant highlighted the fact that, although peasants may consider these holdings to be small, they would often have had to make do with much smaller. This is illustrated by actual farm sizes from Italy and Sicily in the 19th-20th centuries (Figure 3.5). This figure shows that many farms in this period were less than one hectare in size (four *iugera*), and so peasants would have had to look elsewhere in order to procure enough food for a household. This could have been by carrying out waged labour, pooling resources, renting land from larger landowners, or by borrowing (Gallant 1991: 84). This is directly comparable to the Roman Italian situation since, as will be seen from the field survey data in Section 3.2, some sites may have been too small to have been viable without such practices. A number of studies have discussed whether or not Roman smallholders would have carried our wage labour, resource sharing or foraging (Kron 2000; Frayn 1975; Mason 1995), and these factors will be discussed further in Chapter 6.



Italy: (Banfield 1958: 181)
Italy: (Bell 1979: 19)
Southern Italy: (Brögger 1971: 37)
Southern Italy: (J. Davis 1973: 76)
Sicily: (Schneider 1969: 175)
Italy: (Silverman 1975: 51)
Italy: (C. White 1980: 85)

Figure 3.5 The size of 19th and 20th century farms in Italy and Sicily (after Gallant 1991: 85, fig. 4.7)

In order to determine how much land a household would have needed to provide subsistence without recourse to such strategies, Gallant (1991: 72-73, 82) calculated dietary needs and land requirements. With a diet consisting of 65% cereals, 25% vegetables and pulses, and 10% in olive oil and wine, he supposed that a family would have required between three and four hectares (12-16 *iugera*) for subsistence if cultivating all the food themselves.

3.1.6 Conclusions

An important question has been raised by the data presented in this chapter: is it possible to categorise large, medium and small estates in the same way throughout the Roman period? For example, as has been pointed out in Section 3.2, Cato's 100 *iugera vinea* has been categorized as being anything from a 'small farm' to a 'large-scale industrial establishment'. The nature of the production and composition of villas is thought to have put a practical limit on their size (Pliny *NH* 18.7.37), and this has been confirmed by the prevalence of medium and small-sized landholdings from field survey results.

Now that the existence of a great variety of sizes of landholding has been attested, is it possible to categorise plots sizes within the study area? White (1970a: 385-388) used classifications of plot size based on work by Dohr (1965: 29ff) to examine holdings of a known size in relation to the resources of an area. These were again the generalised classifications of 'small', 'medium' and 'large'. Smallholdings were classed as having an area of between 10-80 *iugera*, medium-sized estates 80-500 *iugera*, and large estates 500 *iugera* and above. In antiquity it was also recognised that the *villa* (estate), *casa* (cottage), and *tugurium* (peasants hut) were three distinct levels of site definition (Varro *Rust*. 2.10.6; Columella *Rust*. 12.15.1; Potter 1979: 122), but these were not explicitly quantified in terms of actual size. Dividing landholdings into such arbitrary classifications is useful for landscape modelling of the type carried out in this study, but it must be remembered that, by doing so, much of the actual variety is obscured (as shown in Figure 3.5a and b on page 101).

A polarisation of the size of land units can be seen in the sources. The literary evidence tends to highlight only the very small or very large landholdings, as these were generally the units of interest to the reader. This is a common feature of the available evidence and, as such, is visible when all of the data are combined within the database (see Figures 3.2-3.4 above). The general view of the Roman landscape from the literary sources is therefore one of small and very large agricultural units with very little between. This is a view of the landscape at odds with the data recovered from field surveys and from epigraphic evidence across the country, as well as from anthropological data. Such site distributions, derived from field survey, may therefore be used to enable a rough estimate of likely plot sizes for agricultural establishments, based on their proximity to other sites. The following section approaches the known site distributions from the South Etruria field survey to compare to the evidence assessed here, with the aim of creating a range of likely site territories for different types of site in the study area.

3.2 The size of agricultural units in the Middle Tiber Valley

3.2.1 Types of site in the study area

The original surveys concluded that the landscape of South Etruria could be divided into three types with different characteristics. These were: the pre-Roman landscape with small nucleated centres with dependent farmsteads; the Roman landscape consisting of dispersed settlement; and the medieval landscape whose population was concentrated in small hill and promontory towns and villages (Potter 1979: 5). The period 150 BC to AD 100 saw the peak of dispersed rural population in the South Etruria area. As discussed in Chapter 2, this was also a period of mass reorganisation of the landscape, primarily by means of the land settlements of men such as Sulla, Caesar, and Augustus for their veterans (Campbell 2000: liv-lvi).

As stated previously (Section 3.1.2; Potter 1979: 113), it was the Augustan allotments which had the most impact in this area. Most importantly, Potter also asserted that the landscape of the study area was not suited to the type of large agricultural unit believed to be prevalent in the later Empire, and that small landholdings seemed to be the norm (Potter 1979: 125). This theory was based on the density of sites found during the surveys, and was supported by Witcher (2006: 115) who argued that, in addition to unsuitable topography, there were many other reasons why slave-based agriculture was not likely to have been practiced in the study area. These included the availability of labour from Rome, the high land prices discouraging large estates (Ikeguchi 1999/2000: 35), and finally the relatively high density of towns and extensive euergetism. He argued that municipal display was pointless if there were only slaves, rather than citizens to impress.

The re-study of the South Etruria material has provided a wealth of new information regarding the dating and interpretation of sites within the study area (H. Patterson 2004). Regarding agricultural sites, the recent Tiber Valley Project interpretation has divided sites in the database into either farms or villas, based on criteria such as scatter size and the status of material found (Witcher 2006: 97). A distinction between villas and farms was also made, for example, in De Neeve's locational study of Veii (1984: 26). He divided sites into 'capitalist' villas and 'peasant' farms, labels that have connotations of particular productivity and subsistence strategies. Those farms in advantageous locations are described as being outbuildings of larger centres, buildings associated with tenants working for estates, or merely on land unsuitable for villa specialisation. However, he did highlight the problems in applying these terms wholesale to the area. His interpretation assumes that villa culture had precedence over the smaller farms, and therefore may be used to identify areas of cultural phenomena such as tenancy, and that smaller farms were restricted in their choice of location. However, a farm being well situated does not necessarily prove that it was controlled by a larger landlord. For the purposes of this study, however, such considerations do not impact on the probable productive potential of the farm.

A brief assessment of the proportion of villas and farms in the study area, known from the database, is therefore carried out. Farms and villas are not the only types of site within the study area, the database also includes sites such as towns, villages, nucleated settlements, sanctuaries, kiln sites, quarries, and scatters, some of which were used in further models. However, this study is primarily interested in agriculturally oriented settlement, and so only farms and villa sites are assessed in this case.

The Late Republican coverage from the South Etruria database (150-1 BC) consists of 425 sites, whilst the Early Imperial coverage (31 BC-AD 100) has 1,185. There is an overlap of 31 years for these two periods due to the fact that settlement did not change abruptly when Augustus came to power. It does still, however, illustrate the huge increase in visible rural sites. The sites used are villas and farmsteads and are assessed as two distinct groups. *Villae rusticae*, and villas with associated *mausolea* were also database categories, but these are incorporated into the general villa coverage. The sites are also assessed in relation to their region. However, the number of sites from the Sabine region is significantly less than the number from South Etruria, due to the areas fieldwalked during the survey, potentially creating problems in regional assessments due to the small sample size in this area.

Firstly the proportion and density of known farms and villas are calculated, then the study area divided into a grid based around the extents of the 1:10,000 map sheets. From this the proportion of farms and villas within each grid square can be compared (see Witcher in press for another application of this). It can be seen in Figures 3.6 and 3.7 that the densest visible settlement in both periods is in the area closest to the city of Rome, particularly in the *ager Veientanus*. This density increases in the Early Imperial period, and spreads slightly northwards also. In the Late Republic villas outnumber the smaller farms quite substantially in this area. However, in the Early Imperial period we see that the proportion of farms to villas in this area has become almost equal, and in some places farms outnumber the villas.

It is not surprising that there is a high density of villas in this region. The close proximity to the market at Rome meant that land here was probably highly prized (Morley 1996), and so may not have been affordable to many smaller farmers. However, the increase in smaller sites in the Early Imperial period does seem to contradict this. Possible land settlement schemes in the study area may account for this (see above), or, if these are not examples of economically independent smallholders, these farms may instead represent tenants of larger landowners (cf. De Neeve 1984). Alternatively, the increase may be due to the fact that luxury goods were trickling down to the lower classes, and so smaller farms were becoming more archaeologically visible. Also, certain gaps indicate gaps in surveyed area rather than real gaps in settlement, and again account of this must be taken.

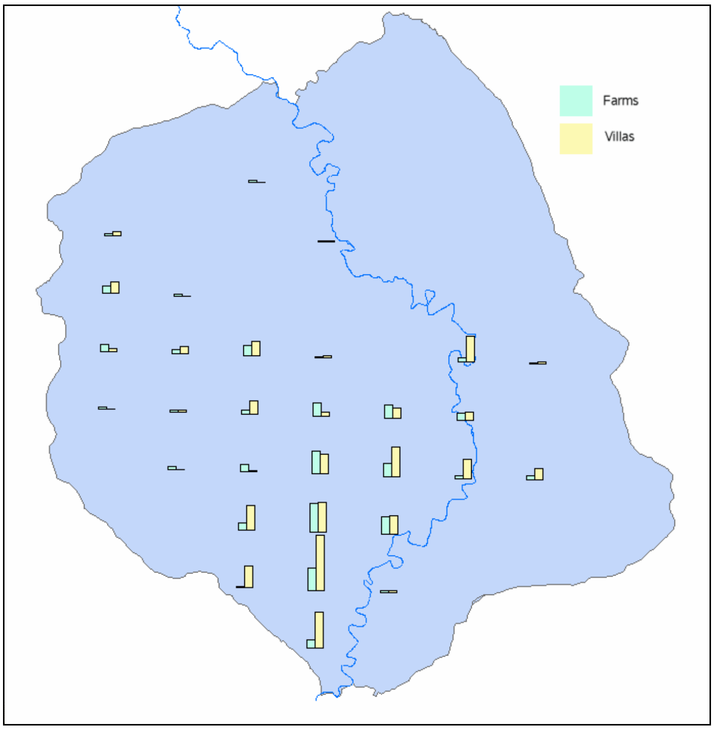


Figure 3.6 Proportion of farms to villas in the Late Republic

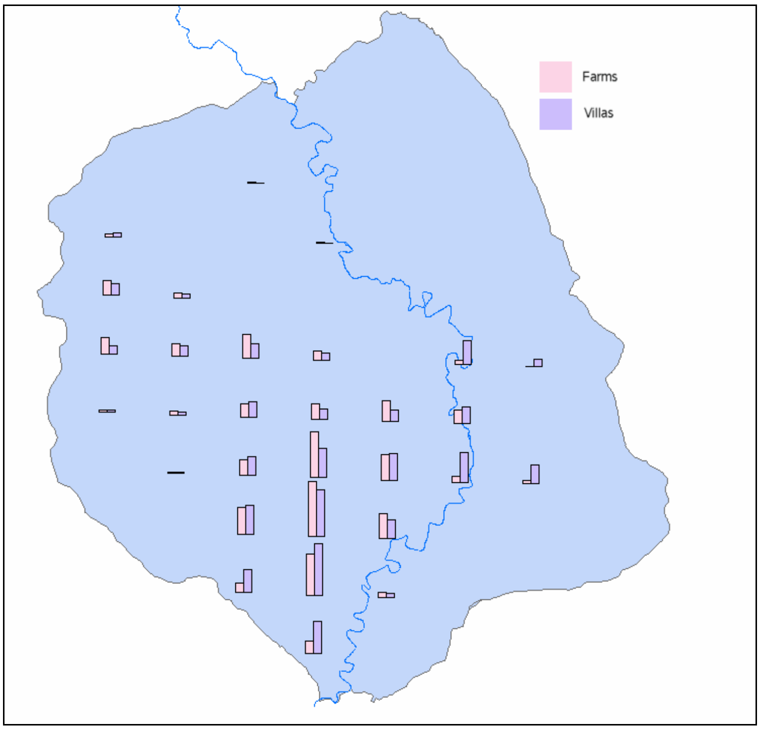


Figure 3.7 Proportion of farms to villas in the Early Imperial period

In the Sabine region to the east of the Tiber, villas outnumber the smaller farms in both periods, although data for this area are much more limited than across the river, and it is highly probable that the few surveys have targeted higher profile sites. Modern farmers consider this region more suitable for oleoculture. The growing of olives requires a substantial amount of capital to run and so may have meant that it was only economically feasible for richer landowners to carry out on any great scale. Arable agriculture is not impossible in this area, but the nature of the terrain and the thinner soils may have meant that this activity was generally avoided, or carried out in conjunction with other types of cultivation, thereby potentially reducing the number of small farmers in the region.

In the north-central region of the study area, between Capena and Sutri, farms are less numerous than villas in the Late Republic. This situation changes in the Early Imperial period to farms being more numerous, a similar pattern to that happening closer to Rome, except that settlement is less dense in this area. The proportions, however, are not so profoundly different as they are in the more southerly regions, with many areas having roughly equal proportions of both types of rural site.

3.2.2 Determining territories for known sites

Information was available from the South Etruria survey data regarding the geographical positions of all the known Roman sites in the study area. It was therefore decided to measure the distances between these sites and investigate their potential territories, in order to compare these with the sizes from the ancient sources in the database.

As discussed in Chapter 2.2.4, the original surveys and excavations discussed potential plot sizes for some villas and farms in the study area. Specific references to landholdings in South Etruria highlight a great variety in the region. For example, the possible veteran allotments on the Monte Forco ridge (Jones 1963: 146-148) indicate smallholdings, whilst further up the scale, agricultural units around the lake of Monterosi, between Lago di Bracciano and Nepi, seem to have been reasonably large estates, interspersed with tracts of woodland. Nearby Sutri is thought to have contained smaller farmsteads (Ward-Perkins 1970: 12). At the top end of the scale are the luxurious villas, such as that at *Lucus Feroniae* which, despite its opulence, also contained the trappings of a working farm (Potter 1980). These varied considerably across the region and so no standard size of plot is realistically attainable for the study area as a whole. However, this variety is not a problem when carrying out modelling of this kind. Benchmark figures for farms and villas may be used to gauge production, but a number of models can be tested in order to determine the effects of differently sized territories.

As surveys themselves are fraught with many problems of interpretation, deriving territories from this data can also be problematic. The tendency to categorise landholdings into 'small', 'medium' or 'large' plots disguises the vast variability of such sites. Furthermore, it is not known if the known sites were occupied at the same time, whilst a number of sites may remain un-recovered, both problems potentially making the likely territories of these sites vastly different. Likewise, the opulence of the site may not necessarily reflect the size of the total holding. As pointed out by Morley (1996: 99), adopting the term '*villa*' for larger sites in the study area implies not only comparability with other surveys, but also the adoption of a unified mode of production associated with such establishments. A well-to-do villa may not necessarily have been associated with a large estate, especially within the hinterland of Rome. As an illustration of this, it has been argued that the area's proximity to Rome meant that the most sensible way of exploiting this land was with smaller, intensive units dedicated to market-goods (Morley 1996: 101-102). This fits well with the density of settlement in the area, as discussed below.

3.2.3 Deriving territories from the South Etruria survey data

As the data from the surveys is particularly dense, territories were allocated to each site. This was done using a GIS allocation module, which essentially carves up the available space in the landscape, leaving no space between. This is based on the geometric properties of the site distributions, and allocates each pixel to its closest site and is analogous to the construction of Thiessen polygons. This process creates boundaries around point distributions, dividing the area to enclose those regions closest to a particular point, as shown in Figure 3.8.

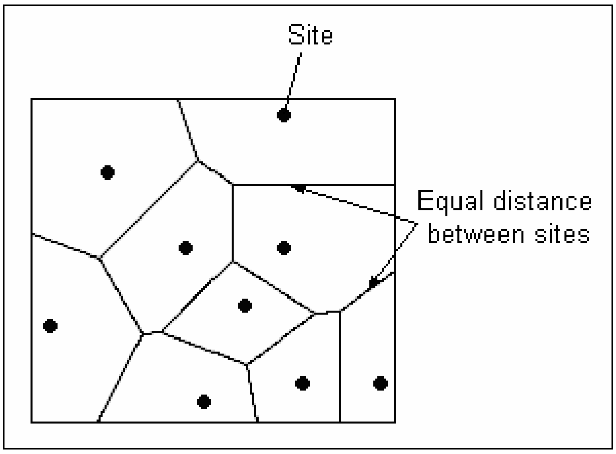


Figure 3.8 Illustration of Thiessen polygons

This analysis was carried out for *all* rural sites (villas, farms and other rural site types) from the Early Imperial period (Figure 3.9). This analysis produced a number of territories of vastly different size – it is also possible to see the sheer density of sites in the central regions, becoming denser towards Rome.

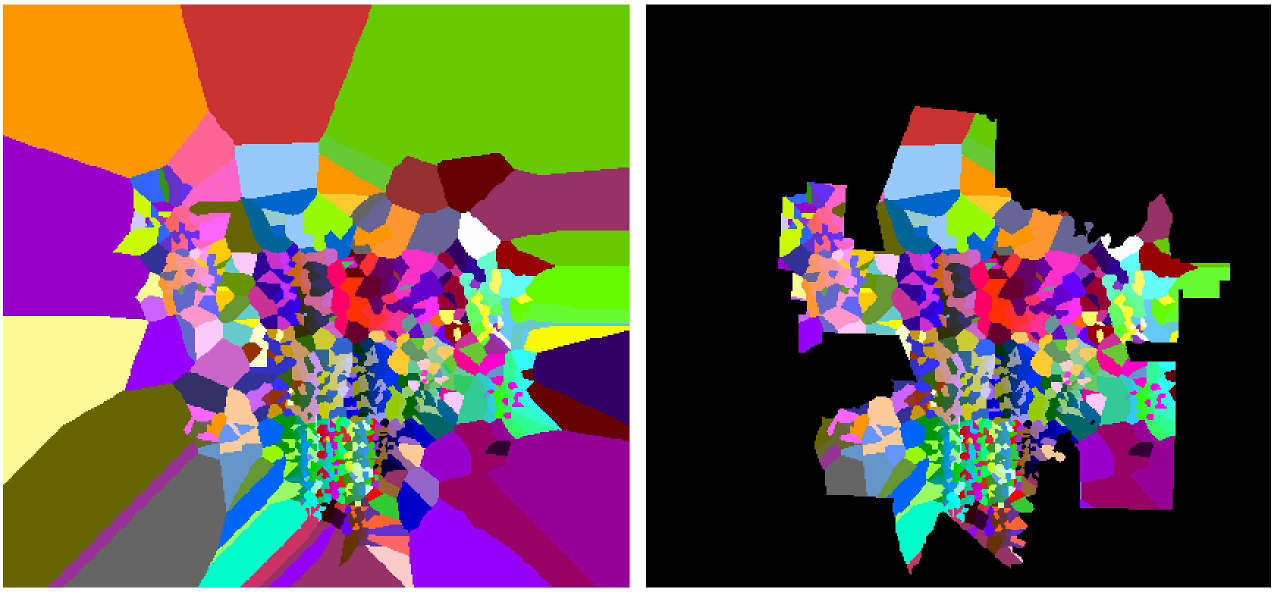


Figure 3.9 a) Rural allocation map for Early Imperial sites, and b) overlaid with the survey outlines

Despite the intensity of the South Etruria survey, however, there are some areas that remain un-surveyed, as well as the issue of recovery rate discussed above (Chapter 2.2.4). This leads to problems creating such a network, as gaps in the data can create huge territories in some areas, particularly at the edges of the surveyed areas. The large outer polygons that are shown in the allocation map (Figure 3.9a) are due to these gaps and as such must be discounted from the analysis. The survey outlines were used as a mask and overlaid onto the allocated data (Figure 3.9b). This therefore excluded areas of no data, but many more large outer polygons remained than was likely to have been the case. This accounts for many of the entries in the 500+ *iugera* category below (Table 3.3).

Table 3.3 Number of sites using White and Dohr's classification

Landholding size	Early Imperial sites
1-80 *iugera*	103
80-500 *iugera*	780
500+ *iugera*	291

The minimum site size for an agricultural unit was 17 *iugera* (*c*.4ha, see Appendix II, Table II.1). However, the vast majority of sites, assuming a fully cultivated landscape, fell into categories above 80 *iugera*. These sites comprise a huge percentage of the sample, and these classifications therefore disguise the wide variety of plot size. In this scenario, the very smallest sites could have operated as part of a larger estate.

There are many problems with this approach, however, not least the assumption of a fully surveyed area and the recovery of 100% of sites. The likelihood that the landscape would have been divided in such extreme fashion is very low and such an intensive use of the soil would have quickly led to exhaustion and poor returns unless fallowed (see Chapter 6). Consequently, a different approach was required.

An alternative method was devised to give a maximum output for the known sites, whereby circular territories were created dependent on the proximity of the closest neighbouring site. In order to generate different territory sizes, the map showing every Early Imperial site was used to measure the distance from each site to its nearest neighbour. These figures were then used to create individual circular territories of different sizes for all farms and villas, thereby taking account of the locations of other types of site, and avoiding any potential overlap. This does have similar drawbacks to the use of Thiessen polygons as, where there are gaps in the survey data, large plots are generated that distort the results somewhat (Figure 3.10).

However, if we use the same size classification as White the difference between the Thiessen size results and the circular territories can be compared (Table 3.4). These results show that the technique gives a significantly higher number of smaller territories than the previous assessment, and is more consistent with settlement in the study area as interpreted by Potter.

Table 3.4. Number of Early Imperial sites in each category

	Number of sites	
Landholding size	Thiessen model	Circular territories
1-80 iugera	103	720
80-500 *iugera*	780	369
500-2000 *iugera*	291	34

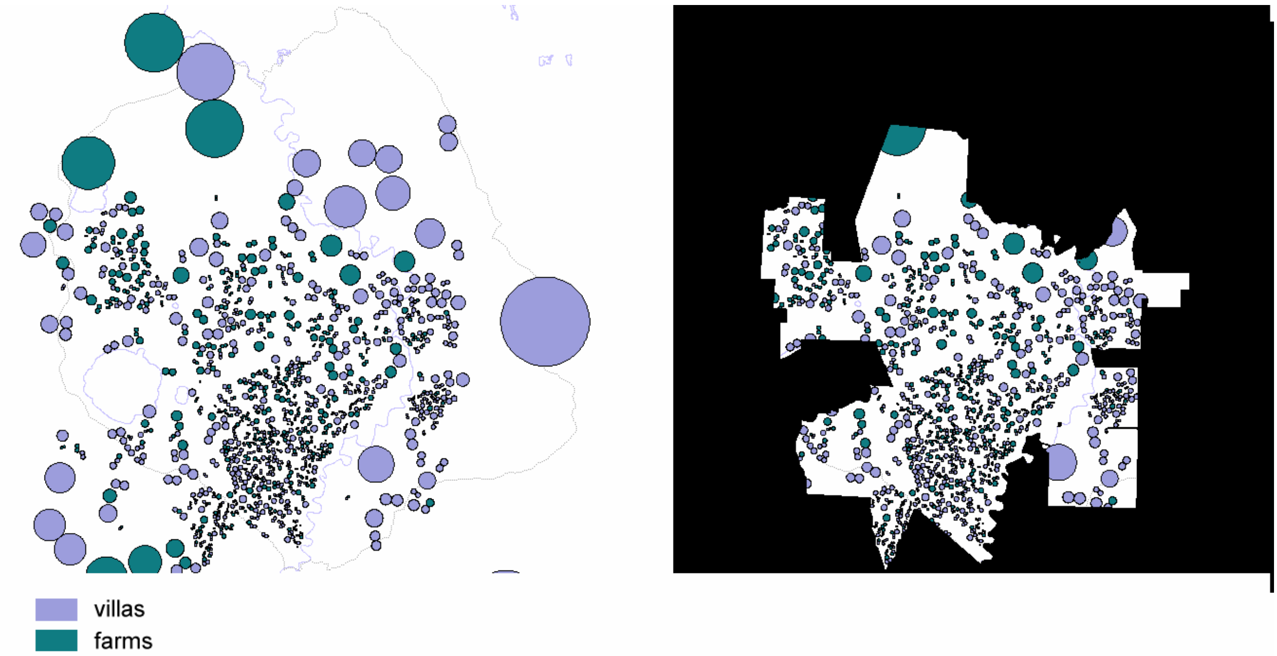


Figure 3.10 Territories based on the proximity of the closest site

Table 3.5 Number of sites and their potential territories

Landholding size in *iugera*	Number of sites		% of sites	
	villas	farms	villas	farms
0-10	14	24	2	5
10-20	40	41	6	8
20-30	59	67	9	13
30-40	84	74	13	15
40-50	57	37	9	7
50-60	69	65	11	13
60-70	19	15	3	3
70-80	32	23	5	5
80-90	25	12	4	2
90-100	24	10	4	2
100-150	68	54	11	11
150-200	33	16	5	3
200-250	27	22	4	4
250-300	21	8	3	2
300-400	25	12	4	2
400-500	6	6	1	1
500+	22	12	4	2

The minimum size for a farm according to the circular territories method was 1.5 *iugera*, which occurred only twice in the analysis (Appendix II, Table II.2). The smallest villa was only three *iugera*, extremely small for a villa site, and this may be an artificial reduction of territory due to the proximity of a smaller holding. In Table 3.5 it is seen that the majority of both farms and villas were between 31-40 *iugera* in size. Cumulatively, approximately 50% of the villas were under 60 *iugera* and 50% of the farms under 50 *iugera* in size. The very small villa territories, as stated above, could be due to their proximity to a site interpreted as a farm, which might instead have been an outbuilding or other associated structure on a larger estate (cf. De Neeve 1984). The table, however, does demonstrate that this method produces a great deal more sites in the smaller categories, unlike the previous method. One of the major problems, however, is that, as we are dealing with survey data, it is highly unlikely that all of the sites from these periods have been recovered. This means that we may be assigning territories that are too large, incorporating the territory of adjacent sites that have not been recovered.

To avoid such problems, it was decided to measure the distances between each site to establish whether a pattern emerged. This was carried out firstly with all rural sites (both villas and farms), and then on a coverage just containing villas. The former was done to give the smallest possible territories for each site, whilst the latter was done to give an indication of the possible size of the larger agricultural units in the region, without any inaccuracies introduced by the proximity of farms that may actually represent outbuildings of larger estates. The distance between each site and its nearest two neighbours was measured within the GIS. The results for both the closest and the mean of the closest two sites were then analysed. To determine the potential territory size, circular buffers were created based upon half the distance (in order to divide the territory between each site) and the area calculated.

Table 3.6 Number of sites located at distances between all Early Imperial rural sites

Distance in metres	Equivalent in *iugera*	No. of sites		Cumulative %	
		Closest site	Closest two sites	Closest site	Closest two sites
0-100	0-3	4	1	0.34	0.08
100-200	3-13	100	43	8.75	3.70
200-300	13-28	266	145	31.12	15.90
300-400	28-50	207	215	48.53	33.98
400-500	50-79	181	221	63.75	52.57
500-600	79-113	163	163	77.46	66.27
600-700	113-154	68	110	83.18	75.53
700-800	154-202	52	69	87.55	81.33
800-900	202-254	42	50	91.08	85.53
900-1000	254-314	33	45	93.86	89.32
1000 +	314+	73	127	100	100

Table 3.7 Distances between Early Imperial villa sites

Distance in metres	Equivalent in *iugera*	No. of sites		Cumulative %	
		Closest site	Closest two sites	Closest site	Closest two sites
0-100	0-3	2	0	0.31	0.00
100-200	3-13	16	4	2.75	0.61
200-300	13-28	72	28	13.76	4.89
300-400	28-50	90	57	27.52	13.61
400-500	50-79	93	90	41.74	27.37
500-600	79-113	108	85	58.26	40.37
600-700	113-154	63	93	67.89	54.59
700-800	154-202	51	61	75.69	63.91
800-900	202-254	32	58	80.58	72.78
900-1000	254-314	29	32	85.02	77.68
1000 +	314+	98	146	100.00	100.00

The results show that the majority of rural sites were situated less than 500 metres apart, giving territories of under 80 *iugera*. A large proportion of these had potential territories of between 3-50 *iugera*. For the villa-only coverage, these potential territories were higher, with the majority fewer than 700 metres apart, giving territories of between 50-150 *iugera*. These are not particularly large for villa estate sizes, as highlighted in the earlier discussion, but neither are they at odds with the lower models from the agricultural sources (e.g. Cato's 100 *iugera vinea*).

These territories are significantly smaller than those derived using both the allocation method and the differently-sized circular buffers, but (despite some similarities) are small when compared with the data from the sources. Plot sizes for the smallest villas are smaller than many of the veteran allotments for farmsteads. The smallest farm size is only slightly larger than the *heredium* of two *iugera*, and the villa plots smaller than many of those described in the literary references. The close proximity of villas in certain areas, particularly close to

Rome, has enforced a limit on the size of those in the rest of the study area. Obviously there will have been variety in villa size, and by attempting to gauge a single figure for villa or farm size we are obscuring this, but the results show that there are also a number of agricultural units with comparable potential landholdings. If nothing else, this analysis show that Potter was correct in hypothesizing that large-scale landholding was not possible within the study area (Potter 1979: 125).

3.3 Conclusions

Finley (1973: 105) argued that calculating the "*optimum size of a peasant's farm is an obviously meaningless notion*", and this could also be argued for all types of agricultural holding. In some respects he is correct, as the size of this type of farm or estate depended on many factors such as fertility of plot, crop grown, and size of household. The inherent difficulties in such calculations have been demonstrated above (Section 3.1) and, depending on the technique used, a wide range of potential sizes for plots in the study area is produced. However, it does not alter the fact that it is a useful exercise to attempt to gauge potential plot sizes – indeed Finley himself went on to carry out a similar analysis, formulating a basic assessment of 10 *iugera* Caesarian allotments (1973: 105-106). Furthermore, a number of important results also emerge. By measuring distances between sites, it is seen that farms and villas were densely settled, thereby limiting generally the size of the units in the area to below 100 *iugera*. The most common farm and villa sizes therefore equate to the 'small' category of site as determined by White and Dohr (Section 3.1.6).

An alternative method of calculating unit size is to determine the amount of land required to provide subsistence for a household, as discussed briefly in Section 3.1.5. However, many ancient farms are considered too small to do this, as diets were often supplemented by foraging from other uncultivated land, or by working as labourers for other landowners (see Chapter 6 for further discussion). Garnsey argued that "*peasants have always been systematic foragers on uncultivated land*" (1988: 53, 46), and other studies have also assumed similar access to resources such as woodland and *ager publicus*, as well as other incomes from activities such as hired labour (Brunt 1971a: 194; 1972: 158; White 1970a: 336). Examination of the results of the distance graphing between sites in South Etruria (Section 3.2.3) may, however, potentially explain the existence of very small plots that at first glance appear to be economically unviable.

With the calculations performed in this chapter a number of assumptions are made. Not all estates or farms would have been so consistent in their size or shape. Some calculations assume a circular territory, and by assuming this, we disregard the possibility of plots of different configurations, such as strips or squares. Indeed the villa or farms need not lie in the centre of the plot, or the area cultivated may not have been proximate to the home. This means that such agricultural units could have farmed much larger areas than is calculated here. As an example, the sites on the Monte Forco ridge investigated by Jones (1963: 49) were between 100 and 130 metres apart. If our calculations were applied to these plots, we would end up with plots of only three *iugera*. However, Jones determined plots of 10 *iugera* due to the nature of the terrain and natural barriers, based on inspection of the landscape during survey and excavation. Nevertheless, he did state that only around half of this land would have been cultivable, due to the slope and likely presence of scrub.

We are assuming also that each farm or villa used its entire territory, but not everyone would have been physically capable of farming large areas, due to the amount of manpower available (see Chapter 7). Alternatively the area farmed may have been limited by fallowing regimes, as well as by limits of ownership or other socio-political reasons. Also, we do not know the number of un-recovered sites within this landscape, which could impact heavily on the distribution of sites. Nonetheless, the sizes chosen are a useful gauge of model production figures for the area, testing the historical sources. Using the different techniques outlined here, different sized territories can be modelled, giving a range of production figures for the area.

For further models a range of buffer sizes was therefore chosen. These were based partly on the results given here, and partly on the sizes from the sources. For example, the absolute minimum distance between survey sites was 70.71 metres, giving a territory of only 1.6 *iugera*, and so the *heredium* of two *iugera* was used as the smallest territory. Also used were the veteran allotments of twelve and forty *iugera*, which are slightly smaller than the plots derived from sites 200 and 400 metres apart, thereby allowing some buffering of the boundaries between sites. The range of possibilities thus produced will therefore encompass any variety, giving a minimum and maximum figure for the region. No sites larger than 240 *iugera* were used. Though perhaps not really representing reality this was because, as settlement was so dense in many areas, any territory larger than 100 *iugera* caused too much overlap for effective modelling.

Table 3.8 Agricultural units to be used in further models

Size of plot	Source
2 iugera	Romulus' historic *heredium*
5 iugera	Common distance between sites in the database
12 iugera	Veteran allotments / 200 metre distance
28 iugera	300 metre distance
40 iugera	Veteran allotments / 400 metre distance
100 iugera	Cato's model vineyard
240 iugera	Cato's model oliveyard

To conclude, it has been shown that White and Dohr's basic classifications of site size obscure the huge variety of potential plot size in the study area. Therefore, some reassessment of the terms 'large', 'medium' and 'small' is necessary, and this is the case across the Empire. The evidence collated within the database shows that site size varied widely across the peninsula (and doubtless in the Provinces also), as well as across time. This means therefore that what may be considered small in one area or period may not necessarily be considered small in another. Linked to this is the fact that, when looking at the physical size of plots, no account is taken of productivity, and so a 10 *iugera* plot in one area could support many more people if situated in a different area. Likewise, when examining other field survey results, the assessment of site size is relative to the area of study. The following chapters will therefore assess the location of sites in relation to resources within the study area. This will be followed by an assessment of the potential productivity of both the landscape as a whole, and a range of agricultural units based on the sizes determined here.

4 LOCATIONAL ANALYSIS OF SITES IN THE MIDDLE TIBER VALLEY

The aim of this chapter is to assess the criteria used by the Roman farmers to choose the locations of their sites within the study area. Using Roman sites gleaned from the South Etruria site database, an assessment of their available local resources is carried out. Determining where sites were positioned in relation to these resources may help to highlight which may have been considered 'desirable' resources during the Late Republic and Early Empire. It will then be possible to assess the likely territories of these sites, as derived in Chapter 3, and their productive potential. The territory sizes calculated in the previous chapter will then be used to test more accurately the economic viability of farms in the Middle Tiber Valley and their possible functions. This will not, however, tell us the productive reality of this area, merely a potential that may or may not have been realised. The analysis is carried out on two different datasets – the Late Republican sites and those from the Early Imperial period. Although agricultural potential remains essentially static, these data give us two 'snapshots' of which resources were considered advantageous, and how this may have changed between the two periods.

For locational analysis, the two regions were assessed together initially, but further analysis then attempted to discern any regional differences between the two areas, which are subject to different landscape conditions that may colour the development of settlement and economy. This will be a difficult matter as recovered sites from South Etruria are far more numerous than in the Sabine region; 87% of all rural sites are situated in South Etruria making the use of the Sabine sample problematic. This small sample, and the lack of field survey in the more topographically challenging areas means that results must be used with caution, but an assessment may still show some regional difference.

Firstly, however, a general assessment of the landscape and resources of the whole study area is carried out. The methodology used here to determine which resources were preferred in the Roman period is a combination of different techniques. Firstly sites and their location in relation to resources are analysed to detect any potential patterns in land use. An alternative method is then followed whereby the evidence from the agronomists and other sources are used to create suitability maps for different types of economies, independently of the archaeological data. The Roman sites from the database are then overlaid to see whether they conform to the recommendations of the sources. The resulting maps are employed in later chapters in combination with the site sizes (or catchments) established in Chapter 3, in order to ascertain available catchment resources and production potential.

The locational analysis is carried out using modules within the *Idrisi* GIS. Statistics are extracted from thematic layers (e.g. slope, geology) based on the locations of known sites. These are then assessed to determine whether any patterns emerge. The significance of these potential patterns is then tested statistically. The Chi-Squared (χ^2) test is used on the nominal datasets, i.e. data with discrete categories such as geology type or land use, to see if the distributions of sites on certain resources was normal (Robinson 1998: 60-64; Wheatley and Gillings 2002: 136-139).

The χ^2 test is a non-parametric test (i.e. using flexible parameters) that is used very widely within geographical applications for hypothesis testing. Here it is used to test whether the distribution of sites in relation to certain resources was by chance, or merely due to the size of the sample. For example, do more sites appear on a particular type of geology purely because that geology type covers the largest area, or is there more significance in the choice of area? By carrying out such tests we may ascertain the degree of preference in site location.

It must be pointed out at this stage that these results are extremely dependent on the quality of the data used. Previous models were run at the beginning of this research using data from the South Etruria database that was not fully interpreted. As such, only a raw spread of sites from the 'Roman' period was available. Sites of varied function, such as towns, villa sites, kilns, sanctuaries, surface scatters, and so on were all grouped together, as well as covering a very long time period of over 1,000 years. The lack of interpretation was problematic for the locational analysis as sites of different function have need of different resources. For example, agricultural sites may appear on good soils, but kilns may require a nearby clay source. Clay is not good for ploughing as it produces a heavy soil that is difficult to work. Likewise, agricultural sites tend to be situated on reasonably flat slopes and low altitudes, yet a sanctuary may be positioned in a remote area, for example on mountain tops or in secluded woodland. The sites have since been interpreted as part of the Tiber Valley Project however and, as such, provide a much clearer picture of locational preference as will be seen in the following sections.

4.1 Altitude

The topography of the Middle Tiber Valley is such that extreme heights above sea level are rarely reached. From the Digital Elevation Model it was established that the maximum altitude reached in the study area is 1,269 metres. Very few places in the study area reach such heights, and these tend to be in the outer regions, particularly towards the Apennines in the Sabina.

Altitude has an impact on farming as, the higher one cultivates crops, the longer that crop takes to grow. All crops have an altitude limit whereby the growing cycle becomes so long it ceases to be worthwhile. A long vegetation cycle also puts the crop at greater risk of disease or damage by bad weather. For wheat this altitude limit is between 1,000 and 1,200 metres above sea level (Spurr 1986a: 21), and arable crops will therefore tend to be cultivated at much lower altitudes than this maximum.

Table 4.1 Comparison of the altitude of modern arable and Roman sites

	Modern arable		Late Republican		Early Imperial	
Altitude	No. of ha	%	Rural sites	%	Rural sites	%
0-100	26,644.50	35.12	159	31.99	360	27.21
100-200	22,476.87	29.63	179	36.02	448	33.86
200-300	22,660.65	29.87	109	21.93	378	28.57
300-400	2,901.33	3.82	29	5.84	95	7.18
400-500	831.60	1.10	13	2.62	32	2.42
500-600	132.39	0.17	8	1.61	9	0.68
600-700	79.92	0.11	0		1	0.08
700-800	68.94	0.09	0		0	
800-900	71.46	0.09	0		0	
900-1000	0		0		0	
1000-1100	0		0		0	
1100-1200	0		0		0	
1200-1300	0		0		0	
no data	2159.64		6		18	

In comparing the altitude of modern arable and Roman rural sites (Table 4.1), it is clear that sites are clustered at lower altitudes. No Roman site was situated higher than 700 metres above sea level, as were very few areas of modern arable. The vast majority lay at a height of between 0 and 300 metres. Aside from cultivation practice, this could be due to a number of factors. It could relate to biases within fieldwalked areas (i.e. did they avoid walking steep hills), or post-depositional processes affecting the location of finds. Many of the higher hills within the study area are also in the Sabine region, much of which has not been surveyed. This causes sampling problems, as it cannot be determined with certainty whether the sample follows any pattern. It can be assumed, nevertheless, that more extreme altitudes were likely to have been avoided for cultivation reasons, or that these areas corresponded with other limiting factors, but an element of uncertainty must remain.

Carrying out a Chi-Squared test on the data, the average altitude of Roman rural sites of both periods were compared to a background mean of the area surveyed within the study area (Table 4.2). This was to try and remove any bias in the data caused by unsurveyed areas in more mountainous regions.

Table 4.2 Chi-squared test on elevation (divided into 100m classes)

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	174.37 m asl	165.37m asl	13.67	α = 0.05	12.59	6	YES
LR villas		139.66m asl	28.53	α = 0.001	22.46		YES
EI farms		188.28m asl	30.61	α = 0.001	22.46		YES
EI villas		161.56m asl	22.39	α = 0.005	18.55		YES

According to the results, all the analyses are significant, though at different levels. With the exception of Early Imperial farms, all sites types fall at lower altitudes on average than the area's mean as a whole. Could this therefore be showing that villas are sited preferentially at lower altitudes? This is particularly significant when compared to farms of the Early Imperial period, which are the only site type to be at higher altitudes than the background mean, possibly indicating a decrease in suitable areas after settlement increase.

4.2 Slope

Slope is a very important aspect within agriculture, as agricultural work becomes more difficult the steeper the gradient. However, before one discusses elements of topography in the Roman period, it must be noted that the modern terrain does not necessarily reflect the topography of the Roman period. Landscape changes occur through both natural and man-made causes, such as large-scale slope erosion, or the raising of valley floors by alluviation. Geomorphological work carried out on the river valley has indicated that the major alluviation event of the Late Antique or medieval period (Vita-Finzi's "Younger Fill") produced deposits of several metres (Vita-Finzi 1969; in Brown and Ellis 1995: 49, 65). This is known from the discovery of a Roman viaduct over the River Treia near Civita Castellana (Brown and Ellis 1995: 56), and a bathhouse at Valchetta near Veii (Jones 1960), both discovered in areas where the alluvial deposits had eroded.

It is not possible to reconstruct exactly the Roman terrain, but it may be possible to draw attention to areas of greatest change, and incorporate them in the model. This may highlight problem areas in the model, and prevent over-interpretation. With access to earlier topographic maps a simple procedure could be carried out: by digitizing both, one map could be subtracted from the other within a GIS, to highlight areas of erosion, alluviation and other types of landscape change. This was done for an area in the *agro Pontino* for the Regional Pathways to Complexity Project (van Leusen and Feiken 2001). Unfortunately there were insufficient resources to perform this for our study area (particularly given the lack of earlier maps and the resolution of the DEM) but would be useful for any further study, or to complement the model presented here.

Areas of low relief have always been favoured for arable cultivation, but such areas are not extensive within Italy, except in regions such as the Po plain and the Apulian Tavoliere (White 1988: 221). It was therefore necessary to cultivate steeper slopes than would have been favoured in these other regions. The utilisation of steeper slopes could afford some advantages, however. For example, drainage could be poorer or more erratic in very flat areas, a problem well understood by the agronomists (for example Cato *de Agr*. 155). One way of utilising steeper slopes for agriculture is the building of terraces. Terraces, however, are extremely difficult to identify, and even harder to date. We therefore have to rely on ancient sources to assess whether they were employed. The sources do not discuss terracing in any significant way: according to Foxhall (1996: 51) as a practice it was seen as time-consuming and a waste of labour. It must be remembered, however, that what may have been considered a waste for larger estates may not have been the case for the smaller farmer (Foxhall 1996: 59). Alternative techniques for cultivation on slopes, such as trenching, seem to have been favoured for large-scale farms (Columella *Rust.* 2.2.12).

Spurr (1986a: 17) drew attention to Columella's advice against cultivating wheat on steep slopes:

> *…these* [grain] *crops fare better in moderately dry and fertile plains than in steep places*
>
> *Rust.* 1.2.4

Spurr argued also that such advice demonstrated that cultivation in practice did not always occur in the most obvious places, otherwise there would be no need to mention it. Pliny the Elder (*NH* 18.178) wrote also of the cultivation of slopes without the use of oxen and ploughs:

> *Man has such a capacity for labour that he can perform the function of an oxen – at all events mountain folk dispense with this animal and do their ploughing with hoes.*

This implies that manual cultivation, which is not as topographically restricted as the use of ploughs, was prevalent in the more mountainous regions, and that slopes did not restrict agriculture as severely then as they would in modern times.

The effect upon the model, if terracing, trenching or the general manual cultivation of steep slopes were used, would be the increased suitability of steeper slopes than is usual for arable agriculture, especially when compared to modern land use. As we cannot accurately locate or date such structures this is the only indicator of their potential use. The topographic location of both modern arable and Roman sites was therefore assessed. Firstly, a percent slope map was derived from the Digital Elevation Model using a basic module within *Idrisi* (Figure 4.1). The associated statistics showed that the average slope factor of the study area is 8%, indicating a fairly level terrain in many places.

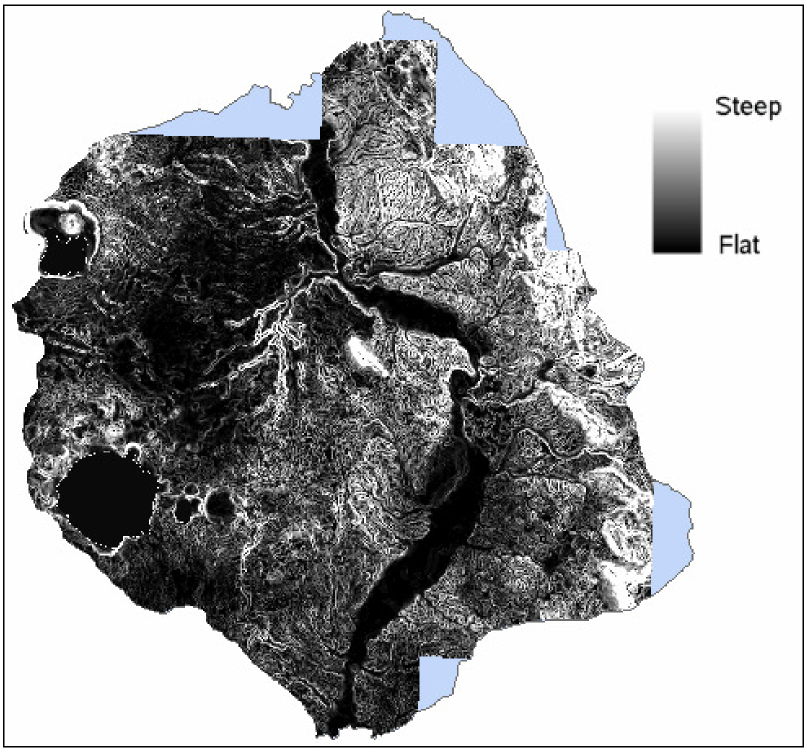


Figure 4.1 Percent slope map of the study area

This slope map was reclassified into categories of 3% in order to facilitate analysis. Firstly the modern arable land, derived from the land use map, was compared to the slope map to see if there was any correlation between slope and land use (Table 4.3).

Table 4.3 Percent slope compared to modern arable land use

% slope	Area of arable in ha	Area of arable in %	Cumulative %
0-3	23,387.13	30.83	30.83
3-6	16,626.78	21.92	52.74
6-9	11,094.21	14.62	67.36
9-12	6,447.42	8.50	75.86
12-15	6,203.61	8.18	84.04
15-18	3,885.21	5.12	89.16
18-21	2,686.95	3.54	92.70
21-24	1,725.57	2.27	94.98
24-27	1,315.62	1.73	96.71
27-30	886.50	1.17	97.88
30-33	624.51	0.82	98.70
33-36	378.81	0.50	99.20
36-39	220.41	0.29	99.49
39-42	125.46	0.17	99.66
42-45	88.02	0.12	99.77
45-48	54.18	0.07	99.85
48-51	32.67	0.04	99.89
51-54	22.50	0.03	99.92
54-57	13.95	0.02	99.94
57-60	10.35	0.01	99.95
60+	37.80	0.05	100

It is noted that nearly 31% of modern arable land lies on slopes of less than 3%, and nearly 90% on slopes below 18%. This overwhelming use of flatter areas is likely to reflect the use of heavy agricultural machinery in the modern period. As previously discussed, it is far harder to operate agricultural machinery on steeper slopes, whereas manual cultivation can be carried out in steeper areas.

Examining the Roman rural sites in the same way (Table 4.4), it is seen that the percentage of sites on slopes of less than 3% is less than the modern arable at only 19% rather than 31%, although cumulatively, a similar number of sites (88-89%) lie on slopes of under 18%. Few sites were located on steep slopes of over 27%, and only one site was known from slopes greater than 60%. This could be a consequence of post-depositional processes encouraging the movement of material down steeper slopes, but it is unlikely that such steep areas would have been used for arable cultivation. This does not, however, mean that they would have been lacking in resources. Steep slopes were often forested and as such had other beneficial resources (see Section 4.7).

Table 4.4 Percent slope compared to Roman rural sites

	Late Republican			Early Imperial		
	No. of sites	%	Cumulative %	No. of sites	%	Cumulative %
no data	6	1.19	1.19	18	1.34	1.34
0-3	89	17.69	18.89	211	15.73	17.08
3-6	108	21.47	40.36	285	21.25	38.33
6-9	97	19.28	59.64	252	18.79	57.12
9-12	49	9.74	69.38	152	11.33	68.46
12-15	59	11.73	81.11	163	12.16	80.61
15-18	41	8.15	89.26	105	7.83	88.44
18-21	23	4.57	93.84	72	5.37	93.81
21-24	17	3.38	97.22	36	2.68	96.50
24-27	7	1.39	98.61	19	1.42	97.91
27-30	3	0.60	99.20	9	0.67	98.58
30-33	1	0.20	99.40	7	0.52	99.11
33-36	3	0.60	100.00	5	0.37	99.48
36-39				2	0.15	99.63
39-42						
42-45				1	0.07	99.70
45-48				2	0.15	99.85
48-51						
51-54						
54-57						
57-60				1	0.07	99.93
60+				1	0.07	100.00

These results show that, when compared with modern arable cultivation, Roman rural sites were not as restricted to very flat slopes. Furthermore, different patterns can be seen within the Roman sites when Late Republican site-slope data are compared with those from the Early Imperial period (Figure 4.2).

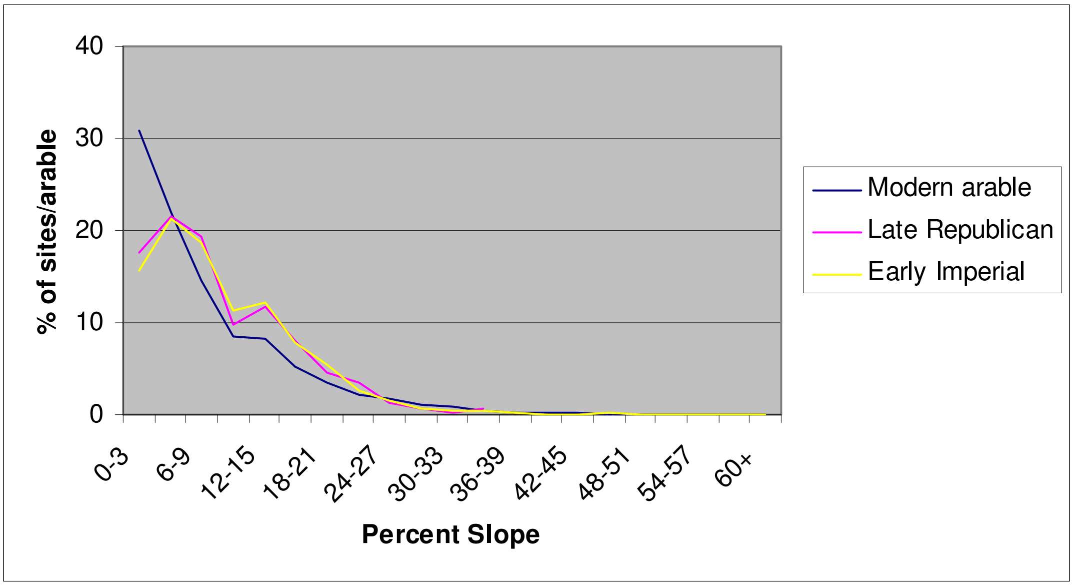


Figure 4.2 Percent slope compared to modern arable land use and Roman rural sites

As is shown in Figure 4.2, comparison between modern arable land use and slope generates a reasonably smooth curve, indicating a generally simple correlation between slope and modern arable land-use. The steeper the slope the less likely it is to be cultivated. This is not apparent for the ancient sites. The graph shows that they are not, as suspected, as reliant on the low-lying areas as modern cultivation. Although the curves are similar in many places, they do show that steeper slopes (18-27%) were utilised more during Roman times than in the modern period. Flat areas are also seen to be utilised less than gently sloping ones. The need for well-drained soils may have led ancient farmers to cultivate steeper slopes, or may be indicative of the use of terracing or trenching.

Table 4.5 Chi-squared test on percent slope

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	11.24%	8.78%	44.09	α = 0.001	29.59	10	YES
LR villas		8.26%	33.36	α = 0.001	29.59		YES
EI farms		9.11%	89.72	α = 0.001	29.59		YES
EI villas		9.19%	73.92	α = 0.001	29.59		YES

Table 4.5 shows that, whilst the background mean for the whole area had a slope percent of 11.24%, all Roman sites were between *c*.8-9%. Chi-squared testing then showed that the location of Roman rural sites on flatter slopes (but not flat!) was significant to the highest level, indicating a strong preference for these types of slope.

The main difference between the Roman and modern period is therefore the increased emphasis on flat areas, probably as a result of the increased use of agricultural machinery in recent times. This is due not just to the restriction of machines to flatter surfaces, but the flatter areas in the study area are also mostly those in the floodplain of the river valley. These areas are characterised by heavy alluvial soils that, although fertile, are difficult to work manually or with ox-drawn ploughs, but are easily cultivated using modern technology. Very flat areas tend also to be those immediately next to the river, and so may well have been prone to flooding. Alternatively, any cultivation marks or archaeological traces may have been obscured by the large-scale alluviation which occurred in the Late Antique or early medieval period (Judson 1963: 899; Brown and Ellis 1995). As stated above, alluvial deposits in the valley can be several metres in depth, therefore obscuring possible sites, which would exaggerate any differences between ancient and modern practice. Furthermore, in areas where the rivers were more migratory, the agricultural potential would have been lower (Brown and Ellis 1995: 69).

4.3 Aspect

For the cultivation of arable, aspect is very important factor as many crops depend on a certain level of sunlight to grow successfully. The analysis of aspect also relates heavily to the climate of the area. Climatic features such as wind direction, rainfall, and frost can all affect the cultivation of crops. Such factors, however, are rarely mentioned in ancient meteorological literature (White 1988: 221).

It has been well documented by the agronomists (see for example Varro *Rust.* 1.39.1, Cato *de Agr.* 1.2-4) that south-facing slopes yielded better than north-facing, and were preferred for cultivation. This was probably due primarily to their receiving the longest hours of sunlight, although there are also the effects of wind direction to consider. Soil warmth has been shown to have been a very important factor in crop growth, although different plants have different preferred temperatures (van Joolen 2003: 27). Assessing the data to see whether or not certain aspects are utilised more than others will again contribute to our understanding of Roman agricultural practice.

Strong winds can cause substantial crop damage, such as flattening of the crop. Prevailing wind direction may therefore have been a factor in choice of land to cultivate. No information is available regarding the prevailing wind direction in the study area during the Roman period, as regular measurements of climatic phenomena such as this were not recorded until much later. However, it is evident that the Romans were aware of its significance: Pliny the Elder (*NH* 18.24) emphasized the importance of wind direction, as well as its nature. Earlier writers were less detailed, their emphasis merely on compass direction and not taking into account other factors (White 1988: 227-228).

> *Wind is injurious to wheat and barley at three seasons – when they are in flower or directly after they have shed their flower or when they are beginning to ripen; at the last stage it shrivels up the grain, while in the preceding cases its influence is to prohibit the seed from forming.*
>
> Pliny *NH* 18.151

The existence of both Greek and Roman anemoscopes demonstrate also their scientific understanding. The Pesaro anemoscope, or windrose, dates from *c.*AD 200, and is a circular piece of Luna marble, discovered on the Via Appia outside the Porta Capena in Rome (Figure 4.3). It was inscribed with the names of the twelve winds with a hole in the centre that has been interpreted as being for holding a pennant (Dilke 1998: 110). However, regular readings were not recorded, or at least have not survived, and so we must rely on modern data for this model. The closest information we have is for the region of Rome, just to the south of the study area. These readings were taken between 1862 and 1910. Wind direction does alter across the peninsula, but by comparison with other station records it is apparent that the reading for Rome is most applicable to the study area.

It is possible that the prevailing wind direction in the Roman period may have been different to today, but we have no way of determining this, due to the lack of recorded statistics. If, however, we assume there to have been little or no change, the location of Roman rural sites on unsuitable slopes could be explained by a number of factors. These could include an ignorance of the detrimental effect of wind, or the belief that sunlight was a more important factor.

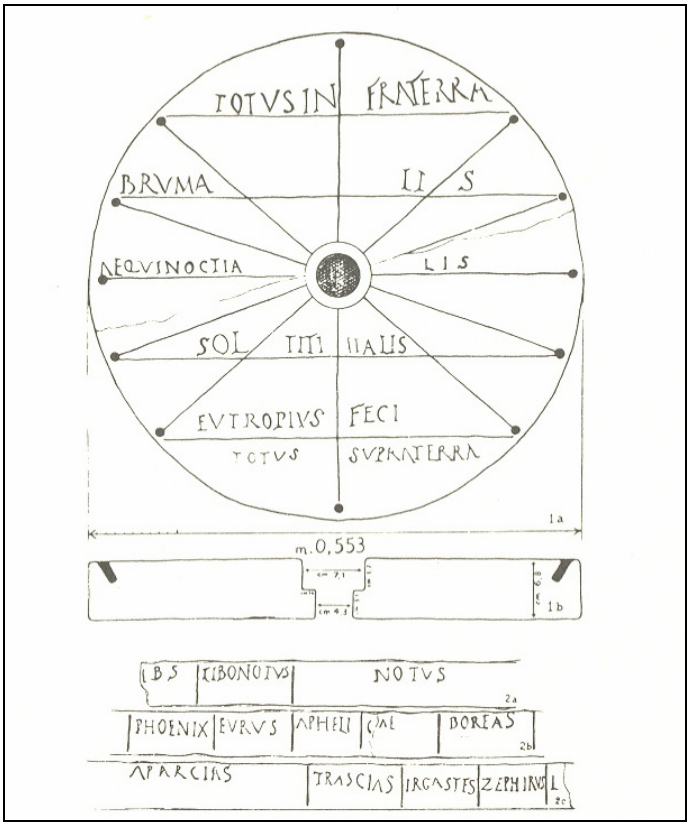


Figure 4.3 The Pesaro anemoscope (Dilke 1998: 111, fig. 21)

Table 4.6 Frequency of wind direction in the Rome area in percent (after Naval Intelligence Division 1945a: 514, tab. 1)

	North	North-east	East	South-east	South	South-west	West	North-west
Jan	57	8	6	5	15	4	4	1
Feb	44	5	4	3	19	13	9	3
Mar	33	5	5	4	19	18	14	2
Apr	28	4	3	3	18	21	20	3
May	24	4	3	3	17	25	20	4
Jun	19	5	2	3	14	33	19	4
Jul	15	6	1	3	15	38	17	5
Aug	25	7	1	2	13	28	21	3
Sep	26	9	2	3	16	24	16	2
Oct	36	6	4	3	20	15	13	3
Nov	49	8	4	4	16	9	6	4
Dec	61	7	6	4	13	4	3	2
Mean	34.75	6.17	3.42	3.33	16.25	19.33	13.5	3

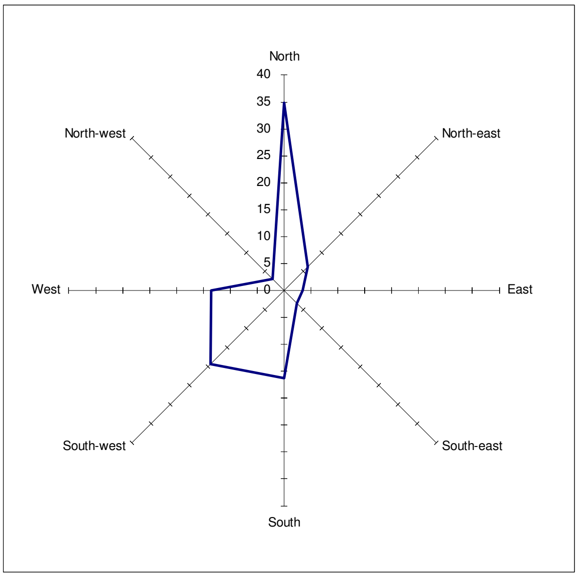


Figure 4.4 Frequency of wind direction from Table 4.6

In Table 4.6 it is shown that north-facing slopes received by far the most wind at nearly 35%, with north-west, east and south-east only receiving about 3% each. Implications for farming mean it can be inferred that north-facing slopes might be less preferred for crop cultivation. Although a variety of wind directions were considered detrimental to different crops by the sources, north-facing seems to have been considered detrimental to many agricultural activities. Pliny the Elder advised against having pruned trees facing north (*NH* 18.328) and that cattle should not be pastured facing this direction as they "*grow sick from the wind*" (*NH* 18.330). It was therefore decided to analyse modern arable land and known Roman sites in relation to aspect to see if this assumption held true.

An aspect map was derived from the Digital Elevation Model and the aspect noted for arable land use as well as for Roman sites. The results are best viewed as a line graph (Figure 4.5).

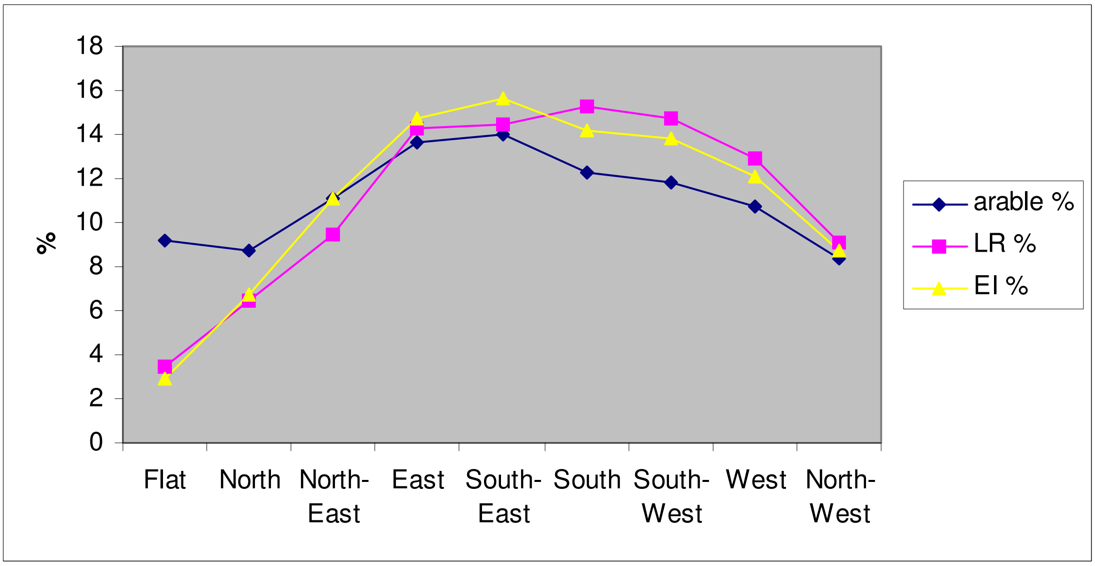


Figure 4.5 Modern arable land use and Roman sites compared to aspect

The results from the Late Republican period show that, in accordance with the ancient sources, rural sites seem to have favoured south-facing slopes. The curve is reasonably smooth, showing adjacent aspects to have had reasonably high numbers of sites also, dropping off towards the north. With the Early Imperial sites as well as the modern arable results, however, we can see that south-east and east, rather than south-facing slopes seem to have been favoured.

Using statistical analysis, it is apparent that the selection of certain slopes was not controlled by their availability. This can be seen in the residual results in Table 4.7 (column (O-E)), which were produced by subtracting the expected numbers of sites (based on the number of hectares covered by each aspect) from the observed numbers. Roman sites seem to have avoided flat areas and those facing north, north-east, west and north-west (or sites in these areas are archaeologically invisible), as indicated by the negative numbers. These figures show that fewer sites occur here than would be expected statistically. The highest residual difference, showing an element of preferential choice, varies between period. For the Late Republican period this is south-facing, closely followed by east. Early Imperial sites appear to have preferred south-east and east-facing slopes. For modern arable the pattern is similar to the Early Imperial period, with an emphasis on east and south-east-facing slopes, although the highest usage appears to be flat land, indicating a change in practice.

Table 4.7 Observed (O) and expected (E) numbers of Roman rural sites and modern arable compared to aspect

	Late Republican				Early Imperial			
	Rural sites	%	Expected	(O-E)	Rural sites	%	Expected	(O-E)
Flat	17	3.42	33.07	-16.07	38	2.87	88.03	-50.03
N	32	6.44	46.71	-14.71	89	6.73	124.34	-35.34
NE	47	9.46	51.25	-4.25	147	11.11	136.42	10.58
E	71	14.29	57.41	13.59	195	14.74	152.82	42.18
SE	72	14.49	61.38	10.62	207	15.65	163.40	43.60
S	76	15.29	60.23	15.77	188	14.21	160.32	27.68
SW	73	14.69	68.08	4.92	183	13.83	181.21	1.79
W	64	12.88	65.45	-1.45	160	12.09	174.22	-14.22
NW	45	9.05	53.43	-8.43	116	8.77	142.24	-26.24
no data	6				18			
				$\chi^2 = 23.7$				$\chi^2 = 73.4$

	Modern arable			
	No. of cells	%	Expected	(O-E)
Flat	77597	9.21	56086.97	21510.03
N	73942	8.77	79226.85	-5284.85
NE	93280	11.07	86923.98	6356.02
E	115286	13.68	97372.98	17913.02
SE	118307	14.03	104111.1	14195.90
S	103098	12.23	102149.8	948.20
SW	99963	11.86	115463.8	-15500.76
W	90680	10.76	111009.1	-20329.14
NW	70821	8.40	90629.42	-19808.42
no data	73942			

The final χ^2 figures for analysis of sites to aspect (Table 4.8) were done on all site types (see full tables in Appendix III, Tables III.I-III.IV). These show that in the Later Republic (with a smaller number of sites) they are significant at the 0.05 and 0.1 level only, whilst in the Early Imperial period they are significant at the 0.05 and 0.001 level, most likely due to the larger sample size showing more pronounced patterns. This means that the null hypothesis – that settlement was not based on any preference for a particular aspect – is rejected, showing that there was an element of choice in the location of Roman sites.

Table 4.8 Chi-squared test on Roman sites and aspect

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	161º (South)	153.92º	15.65	$\alpha = 0.05$	15.51	8	YES
LR villas		154.79º	12.42	$\alpha = 0.1$	13.36		NO
EI farms		149.12º	18.66	$\alpha = 0.05$	15.51		YES
EI villas		154.28º	32.77	$\alpha = 0.001$	26.12		YES

The sites also show preference for south-easterly facing slopes. Now, this might have been assumed to be due to a lack of south-facing slopes, yet the statistics show that, in fact, this is the most typical slope direction in the area, as the background mean is 161 degrees. Re-examining the climatic statistics from the region (Table 4.5) provides a possible explanation for why, for example, north-facing slopes may have been avoided. These slopes receive the highest percentage of wind – nearly 35% of the annual total. This, combined with the small amount of daily sunlight could explain why north- and west-facing slopes tend to have been avoided in both the Roman and modern period. Even though south-east and east aspects do not receive as much sunlight as south-facing slopes, the positioning of modern arable in such locations may indicate a trade-off between the risk of wind damage and sunshine hours.

Although recommended by the agronomists, it is unlikely that the choice of south-facing slopes by Roman farmers was entirely due to their advice. The intended audience for such works were upper class estate owners rather than peasant farmers. Therefore, the choice of such slopes was probably based on farming experience, as the combination of long hours of sunlight and less wind than other aspects would have been the most suitable for such activities. The landscape of the study area as a whole is highly suitable for agriculture under these criteria, as can be seen by the background mean value for many variables. The mean height above sea level is low at only 174m, the mean slope is 11% and the mean aspect is south-facing. It is therefore not surprising that farms and villas could often be positioned in favourable areas, though the statistics do show that they were situated in areas more suitable than these averages.

4.4 Soils

As already discussed in Chapter 1, the soils data for this region is problematic due to the lack of a definitive soil map. Soils are an issue even if we had this data available, as we cannot be sure whether truly reflect the situation in the Roman period, due to their dynamic nature. Soil fertility can change significantly over relatively short periods of time. For example, overgrazing or continual cropping with no fallow can exhaust soils, as can natural erosion or alluviation. The most famous example of severe soil degradation over a short time period is the "Dust Bowl" on the Great Plains of the US in the 1930s. Increased farm size and misuse of the land led to the increased severity of the droughts and dust storms that occurred naturally in this environment. Human-induced wind erosion affected 25 million hectares of land with nearly half of this land suffering severe wind erosion (Gerrard 2000: 180-181). Conversely, natural events, such as the eruption of Vesuvius, can actually increase the fertility of the soil. The weathering of volcanic parent rock can create very fertile soils, as well as the spreading of volcanic ash from eruptions. Andosols are formed from falling ash and pumice, and contain large quantities of fresh weatherable minerals and often have a high organic content (Ellis and Mellor 1995: 216; Gerrard 2000: 131).

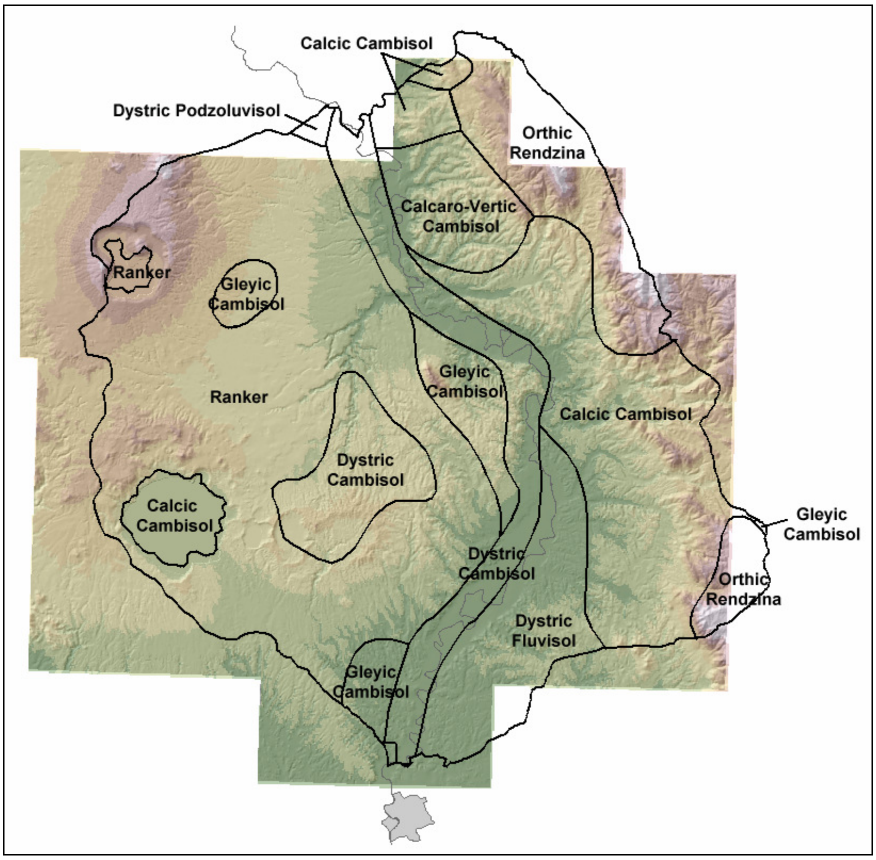
Some subsistence strategies take account of soil exhaustion and practice what is known as 'sustainable agriculture', which can maintain levels of soil fertility over the long term. Some studies, for example the work on the Bronze Age landscape of Gubbio (Malone and Stoddart 1994), have therefore argued that soils are a stable enough resource to use the modern data for modelling. Having this data available may therefore be useful, but any analysis must take account of possible changes.

The development of soils is based on a number of characteristics. The basic soil type is derived from the weathering of the parent rock. However this may also be affected by other external factors such as the vegetation cover (such as woodland, scrub or open fields), the climate, and intensity of land use, and topography (Walker 1967: 87; Bork and Lang 2003: 232). Aspects used within other land evaluations such as surface stoniness or amount of organic material in the soil, unfortunately may not be included without extensive ground survey. We cannot know the extent of damage by factors such as climate and agricultural exploitation, and so it is necessary to rely on the basic soil map alongside the underlying geology to provide a basic index of agricultural potential. The soils within the study area are outlined in Table 4.9.

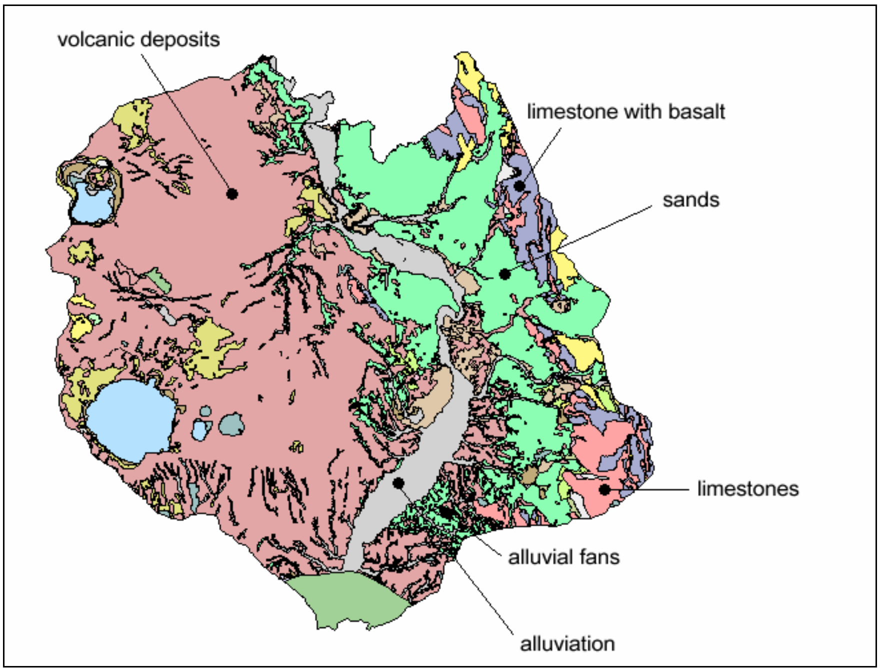
Table 4.9 Soils in the study area

Soil Type	Texture Class (*see below)	Area In Hectares	Area in %
Eutric Fluvisol	Urban	184	0.07
Gleyic Cambisol	2/4	3,262	1.27
Orthic Rendzina	2/3	4,246	1.65
Calcic Cambisol	Lake	5,490	2.13
Dystric Fluvisol	1/2	20,105	7.81
Dystric Cambisol	2	12,480	4.85
Gleyic Cambisol	2/4	7,186	2.79
Gleyic Cambisol	2	2,499	0.97
Ranker	Lake	1,254	0.49
Calcic Cambisol	2/4	42,819	16.64
Calcaro-Vertic Cambisol	3/4	11,621	4.52
Calcic Cambisol	2/4	3,467	1.35
Dystric Cambisol	1/4	21,011	8.17
Ranker	1/2	100,086	38.90
(Dystric) Podzoluvisol	3/4	693	0.27
Chromic Vertisol	3/4	2	0.00
Calcic Cambisol	2/4	1,064	0.41
Orthic Rendzina	2/3	19,814	7.70

It is possible to see, when comparing visually the soil map with the underlying geology, that there are certain correlations (Figure 4.6). For example, the alluviation of the central river valley has produced a dystric cambisol (see below for descriptions). Where the alluvial fans stretch into Sabina to the south of the study area, this has produced a dystric fluvisol. The volcanic geology of South Etruria has produced primarily a ranker soil with a few areas of gleyic and dystric cambisols. The sands and conglomerates overlying the limestone hills of Sabina have produced calcic cambisols and calcaro-vertic cambisols, whilst further into the mountains, towards the east of the study area, the limestones and basalt have weathered to produce orthic rendzinas.



a.



b.

Figure 4.6 Comparison of a) soil and b) geology in the study area

These different soils have different characteristics, related to their fertility, drainage and so on. To understand the implications for farming, probably the most important feature to examine is soil texture. The classes used in the 'Texture Class' column of Table 4.9 (page 142) refer to the percentage of sand or clay present as derived from the soil map (The Commission of the European Communities 1985) and are as follows:

1. Coarse (less than 18% clay and more than 65% sand)
2. Medium (less than 35% clay and more than 15% sand; more than 18% clay if the sand content exceeds 65%
3. Medium fine (less than 35% clay and less than 15% sand)
4. Fine (between 35 and 60% clay)
5. Very fine (more than 60% clay)

It is clear from Table 4.9 (page 142) that most soils are between medium and fine in texture, with only a small number being coarse or fine. The main exception is the large area of ranker soil overlying the volcanic geology of South Etruria. This has a coarse-medium texture class of 1/2, as do the Tiber river valley and other alluvial areas. Soils of a coarse texture are likely to be very well drained, and may therefore require additional water to prevent crops parching. However, it is the very fine soil texture that is most problematic for agriculture. Such soils are very difficult to work due to their heaviness, a result of the high clay content. Table 4.9 shows that the drainage of most soils in the study area will be at a good level, beneficial for agriculture.

The soils in general have already been discussed in Chapter 1, but it is worth restating the general features of each soil type. Cambisols tend to be medium-textured with good structural stability and high porosity. They hold water well and have good internal drainage. In general, cambisols make good agricultural land, with dystric cambisols used for mixed farming and grazing, whilst vertic and calcaric cambisols, if irrigated, are good for food and oil crops (Driessen and Deckers 2001: section 4). This can be seen in the study area, with the majority of olive groves (66%) situated on calcic cambisols, and 23% of the arable land on dystric cambisols (Table 4.10).

Table 4.10 Land use and soils in the study area

Soil type	Arable	%	Olives	%	Vines	%
no data	11	0.001	13	0.004	15	0.53
Eutric Fluvisol	0		0		0	
Gleyic Cambisol	51758	5.97	1886	0.65	0	
Orthic Rendzina	7771	0.90	10760	3.71	0	
Calcic Cambisol	64593	7.45	192573	66.46	810	28.72
Dystric Fluvisol	115741	13.35	17520	6.05	294	10.43
Dystric Cambisol	195758	22.58	5609	1.94	416	14.75
Ranker	403023	46.49	60014	20.71	918	32.55
Calcaro-Vertic Cambisol	26621	3.07	1344	0.46	367	13.01
(Dystric) Podzoluvisol	1694	0.20	47	0.02	0	
Chromic Vertisol	0		0		0	

Fluvisols are naturally fertile and tend to be used for annual crops, orchards and grazing, although some measure of flood control or irrigation is often required. Within the study area, however, only 13% of arable crops are on this soil type. The soil that covers the largest area is a ranker, which is generally believed to be less fertile and poor for agriculture (Driessen and Deckers 2001: section 4), though a large proportion of modern arable (46%), olives (21%) and vines (33%) are grown on this soil type.

This dichotomy could be explained by various reasons. Rankers are poor soils forming generally on steep slopes and so, given the varying topography of the area, this soil type may not really be representative of all soil types in the region. Indeed, the attribute table associated with the soil map shows that many other soil types are present in this particular area. These include ando-dystric cambisols and vitric andosols (associated with the volcanic deposits), orthic luvisols, and eutric lithosols, all of which are richer, more fertile soils.

This demonstrates that the scale of the soil map is too broad to use with great confidence, as well as the fact that, due to the extensive agricultural exploitation, levels of fertility are likely to have changed. We also know from archaeological investigations that soil was formerly more continuous in character, but that significant erosion has led to soil loss in many areas of the Mediterranean (Shiel 1999: 71). It is therefore difficult to use the modern soils alone as an indicator of potential Roman fertility. The underlying geology was consequently analysed in order to assess any potential patterns in land use and fertility.

4.5 Geology

The geological formations of the study area and the modern land use were discussed in detail in Chapter 1. Here it only remains to demonstrate where modern arable and Roman sites were situated in relation to these. The geological differences between the two regions of South Etruria and Sabina is likely to affect agricultural potential as the underlying geology impacts heavily on the soil type produced, as discussed previously. The volcanic sediments underlying a large percentage of the area are of two types – basaltic and trachytic. These are variable in their level of compactness and resistance. In general, however, they are permeable and would tend to create a decent fertile soil, as long as weathering has produced enough soil depth (Walker 1967: 171-2).

Limestone tends to produce a fairly poor soil. The rendzinas discussed briefly above are shallow and generally unproductive. These types of areas are said to be often left as pasture or forest (Walker 1967: 79). Sands and conglomerates, as well as clay, tend to produce soils prone to severe erosion and as such are not particularly conducive to farming. Sands drain too quickly, a serious problem in the Mediterranean, whilst clays bake solid in the summer and are heavy and unworkable in winter without relatively sophisticated ploughs (Walker 1967: 79-80). Crops such as olives, however, are more resistant to such conditions than field crops, and this could explain the predominance of this crop in the Sabine region of the study area.

In order to assess potential fertility, the geology and modern land use maps were cross-tabulated to show which geology types certain land use categories fell on, and if this was significant (Table 4.11). This enabled us to see if certain crops favour certain geology types, or if certain crops were given preferential treatment. Following this, the Roman rural sites were then analysed to see which geology types they tended to fall on, to highlight any differences between ancient and modern practice (Table 4.11).

Numerically, for both modern arable land and Roman sites, the volcanic geology of tuff, pozzolana and ignimbrites was by far the most popular (Figure 4.6). Just over 80% of the Roman sites fell on this type, whilst 64% of modern arable land lay on this geology type. However, this is unsurprising as this type covers the largest number of hectares in the study area. This was followed by sands with 6% of the Roman sites and 5% of the modern arable. Alluvial deposits scored second highest for the modern arable at just over 16%, but contained only 3% of the Roman sites.

Table 4.11 Percentage of modern arable land, modern olives, and Late Republican and Early Imperial rural sites falling on different geology types

	Modern arable	Modern olives	Late Republican	Early Imperial
Quaternary and recent alluvium	19.16	3.38	3.29	3.20
Grey-blue clays and marls	0.06			
Fluvial deposits	2.68	2.25	1.88	2.02
Sandstones with sporadic inclusions of clays and marls	0.28	0.02		0.50
Calcareous sandstones, small organic shell fragments	0.08		0.71	0.42
Conglomerates and cemented rubble (breccias), scree (breccias on slopes)	0.02	0.21		
Micritic limestones and calcareous sandstones	0.13	4.92		0.08
Micritic compacted limestones with cherts, marly limestones and marls	0.27	2.49		0.08
Bedded tuff (layered ash deposit) with variable silt content	0.03	0.65		
Crystalline dolomites and calcareous dolomites	0.02	0.13	0.47	0.17
Bedded jasper, marly limestones and clayey limestones	0.01	0.11		
Nappe debris, weakly or not cemented	0.19	1.84		0.08
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	0.57	0.69	0.47	0.25
Lava flows	4.21	0.46	1.41	1.77
lakes	0.08			
Sands and lacustrine/brackish lagoon silts	0.08			0.08
Marly clays and marls with sandstones interbedded	0.01			
Marl with calcareous intercalations	0.51	3.67		0.17
Marly clay, clay and marls with sandstone alternations	0.05			0.08
Yellow sands and coarser sands cemented	0.14	1.65	0.47	0.42
Sands, often with concretions	8.91	48.78	6.59	5.89
Beach sands, fine to coarse				
Clayey black soils, rich in humus	1.29	0.16		0.08
Travertine, more or less clayey	2.33	1.39	0.94	1.60
Urban areas	2.01		3.29	2.44
Tuff, pozzolana and ignimbrites	56.88	27.12	80.47	80.66

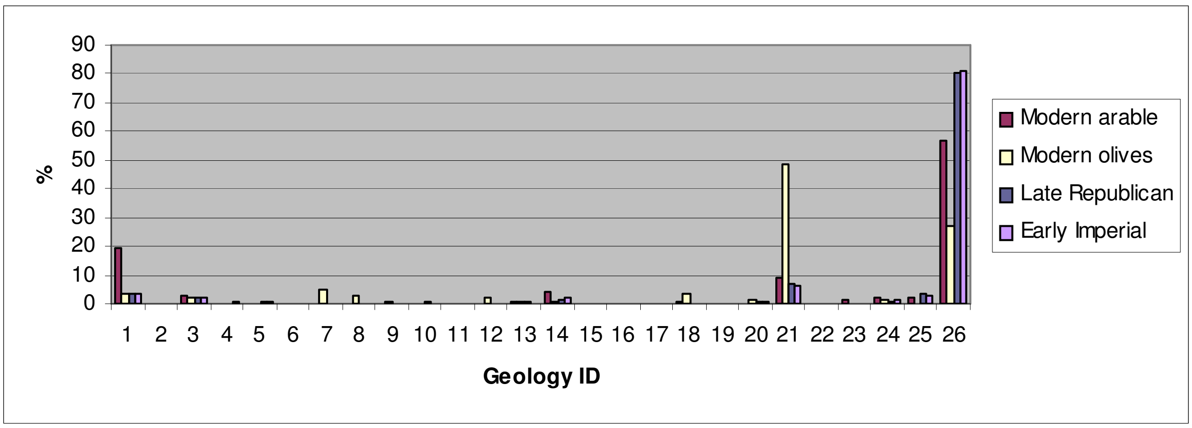


Figure 4.7 Percentage of modern arable, olives, and Roman rural sites on each geology type

It was not possible to perform a meaningful χ^2 analysis on the modern land use dataset, although it was possible to see where certain geology types were used preferentially or avoided (see Appendix III, Table III.6). This table shows that, although the volcanic geology covers the largest area, this is still being used preferentially for arable agriculture in the modern period, as considerably more arable was located on this geology type than would be expected. This is also the case for the alluvial sediments. Sands and limestones, on the other hand, were used significantly less than would be expected based on the area covered. For olives (Table 4.11 above and Appendix III, Table III.7), the comparison shows that sands and limestones are actually the most desirable geology type for cultivation whilst the richer alluvial and volcanic soils are used less than expected.

A more detailed χ^2 analysis for Late Republican and Early Imperial rural sites was carried out in order to see if the apparent preference by Roman rural sites for volcanic geology was statistically significant (Table 4.12, full tables in Appendix III, Tables III.8-11). Overwhelmingly, farms and villas were located preferentially on volcanic soils as almost twice the expected number of sites were situated in these areas. At the other end of the scale, sands and conglomerates and the alluvial deposits were statistically insignificant, despite the high number of sites found on this type. This may have implications for the types of crops cultivated. Comparison with modern land use would seem to imply that volcanic soils are more likely to be cereal-growing areas, whilst limestone and sands would be suitable for olives. However, some areas do show that cereals are sometimes grown on sands, and that complex agriculture occurs on many different types of geology.

Table 4.12 Chi-squared test on geology type

Site type	Background mode	Site mode	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	26 (volcanic)	26	153.09	α = 0.001	48.27	22	YES
LR villas		26	163.12	α = 0.001	48.27		YES
EI farms		26	378.03	α = 0.001	48.27		YES
EI villas		26	305.19	α = 0.001	48.27		YES

As sands were used less by all samples, it is likely that these geology types may have produced soils less suitable for arable farming than the volcanic geology. Alluvial deposits, on the other hand, tend to produce heavier soils, and so their apparent increased cultivation in the modern period may reflect either an improvement of technology, or the low visibility of sites on this geology type. Alluviation has buried a number of sites and so we do not know the full extent of settlement in the valley. However, we know that there had been alluviation previous to Roman settlement, and so the soils here would have been very difficult and heavy to work. For this reason, these types of areas have been said to have been used for the grazing of animals (Morley 1996: 119). White (1988: 224), on the other hand, supposed that field survey was now showing up settlement alongside deposits of such heavy soils which indicated their use for cultivation. Either way, this soil type was not useless agriculturally and would have provided some sort of output, whether pastoral or arable.

4.6 Land use

Land use, again, has been discussed in Chapter 1. Arable is concentrated in South Etruria and is interspersed with large areas of 'complex agriculture'. Olives are dominant within, but not limited to, the Sabine region. In order to study the nature of complex agricultural classes more fully, data was obtained from the *Catasto Gregoriano* (Gregorian Cadastre), which dates from the early 19th century. The cadastre is composed of three series of documents.

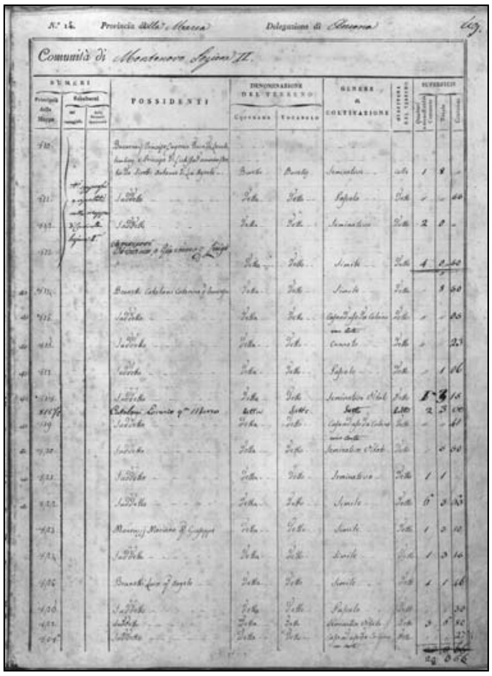
These are the main maps at 1:2,000, as well as smaller-scale maps at 1:4,000 or 1:8,000, and their associated property registers, or *brogliardi* (Archivio di Stato di Roma 2002). These maps show the land use immediately surrounding urban centres in greater detail than the modern land use map. They may therefore be used to demonstrate the presence (or absence) of kitchen-garden style cultivation as well as shedding light on what constitutes complex agriculture. Unfortunately we have information only regarding the immediate environs of the urban centres, and not the surrounding hinterlands.

To address this issue, a sample map was digitised and compared with the 1:50,000 modern land use map. The available maps within the study area included Bassano di Sutri, Bracciano, Campagnano, Castelnuovo di Porto, Magliana, Magliano, Monte Rotondo, Morlupo, Nepi, Orte, Palombara, Poggio Bustone, Poggio Mirteto, Sant' Oreste, Sutri, Torri and Vico (Figure 4.8).

The area of Nepi was chosen, as this was known to have been a Roman urban centre (Figure 4.8). The historic map was rectified to the correct co-ordinates within ArcGIS, using the IGM 1:20,000 road map (Istituto Geografico Militare). The property boundaries shown on the map were then digitised and given land use classifications according to what was grown, as determined from the associated registers. The very dense urban settlement in the centre of the map was not included. This was with the aim of comparing this more detailed information to the overall land use map to try to identify how complex the land use may have been in the Roman period, as compared to the generalised map of modern practice.

Figure 4.8 Location of maps from the Catasto Gregoriano

As can be seen in Figure 4.9, the land use around the town is much more complex than the regional land use map suggests. However, comparison between the two does show that the land use matches broadly in many areas, implying continuity of cultivation since the 1800s. The map also shows how far urbanism has spread in this time, with a much larger occupied area in the more modern regional land use map. The most useful categories, however, are the complex classes, and the cadastral map reveals far more detail in this regard. There is an intermingling of pasture, wheat, olive and vine growing, often intercropped in different combinations, as well as kitchen gardens and managed woodland. The different categories derived from the *brogliardo* are outlined below (Table 4.13).



a. **b.**

Figure 4.9 a) The Catasto Gregoriano for Nepi and b) the associated brogliardo or register (Archivio di Stato di Roma 2002)

Table 4.13 Translated selection of land use categories from the Catasto Gregoriano

Seminativo	Wheat (sometimes with vines or scattered / aligned trees)
Seminativo vitato	Wheat and vines (sometimes supported on trees)
Vigna	Vines
Seminativo con olivi	Wheat intercropped between olive trees
Seminativo vitato con olivi	Vines supported on olive trees with wheat
Seminati con quercie di alto fusto	Wheat with oak trees
Canneto	Cane fields
Orto	Garden
Prato	Meadow
Prato con quercie di alto fusto	Meadow with oak trees
Bosco con quercie di alto fusto	Woodland with oak trees
Pascolo	Pasture
Pascolo cespugliato misto	Pasture with mixed shrub
Pascolo cespugliato forte	Pasture with heavy scrub
Pascolo boscato misto	Pasture with mixed woodland
Pascolo bosco forte	Pasture with heavy woodland
Pascolo boscato dolce	Pasture with light woodland
Bosco misto ceduo	Mixed coppiced woodland
Bosco ceduo forte	Heavy coppiced woodland
Bosco ceduo dolce	Light coppiced woodland

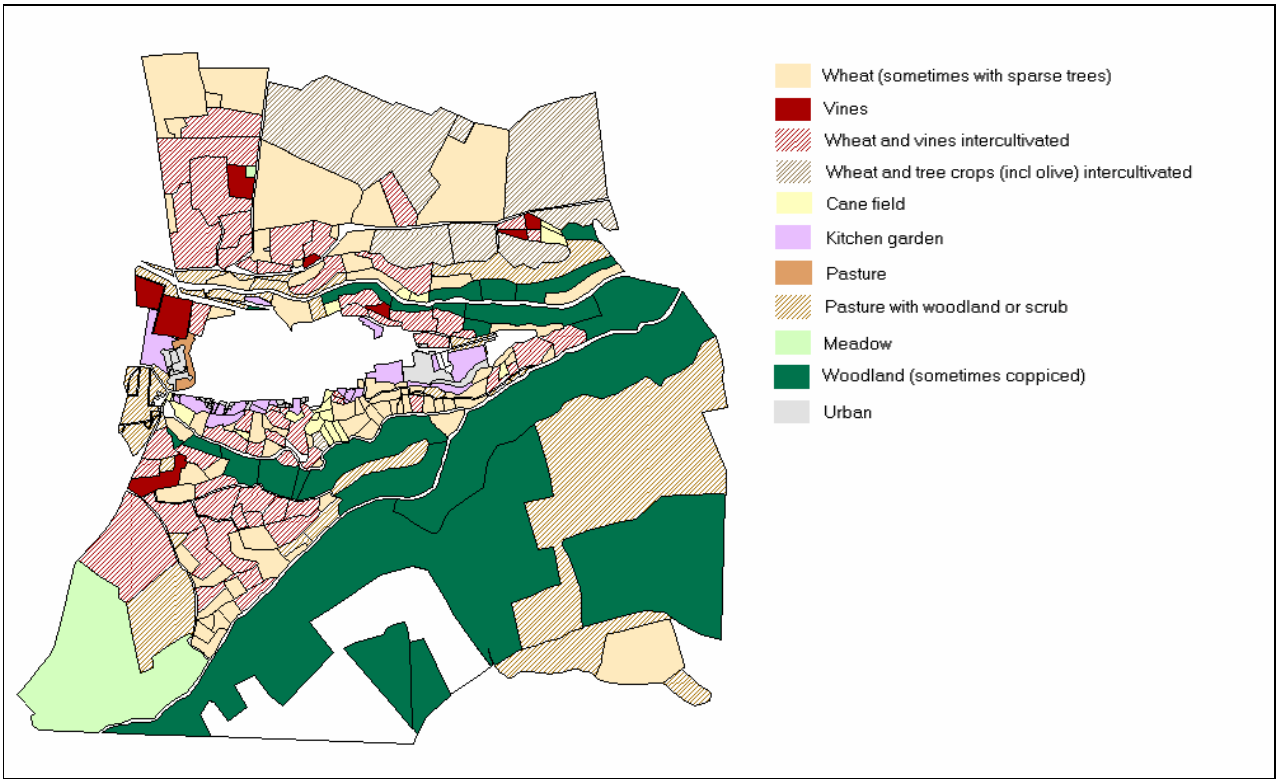


Figure 4.10 Digitised version of the Nepi cadastral map (after Archivio di Stato di Roma 2002)

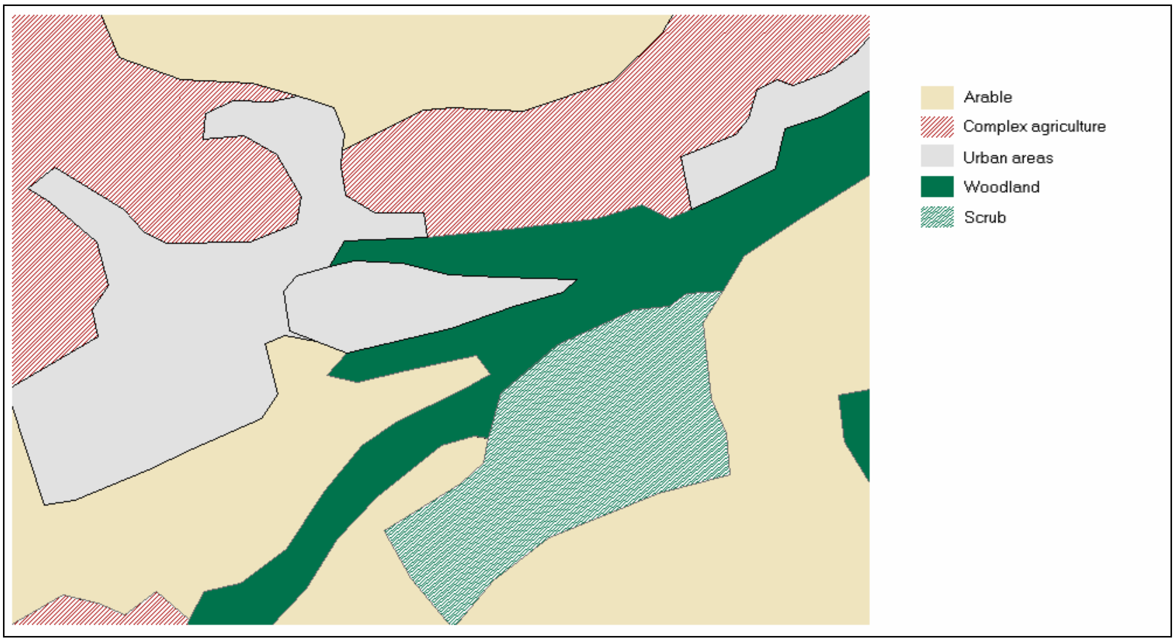


Figure 4.11 The same area from the modern land use map (British School at Rome / Comune di Roma)

The complex classes were grouped into larger categories for the map (Figure 4.10). The statistics from Table 4.14 show that plot sizes ranged a great deal; from tiny parcels of less than a *iugerum* to larger areas of up to 60 *iugera*. The vast majority, however, are small and relate to buildings in the centre of the town. As one moves further from the town, the plots increase in size.

Table 4.14 Land use statistics from the Nepi area

		Minimum	Maximum	Mean	Total	% of whole area
Wheat (sometimes with vines or scattered / aligned trees)	Hectares	0.02	3.84	0.35	26.16	15.02
	Iugera	0.06	15.36	1.41	104.64	
Wheat and vines	Hectares	0.03	3.33	0.44	24.48	14.06
	Iugera	0.11	13.32	1.75	97.94	
Wheat intercultivated with tree crops (including olives)	Hectares	0.13	8.51	2.23	20.05	11.51
	Iugera	0.50	34.04	8.91	80.20	
Vines	Hectares	0.08	0.72	0.32	2.54	1.46
	Iugera	0.32	2.88	1.27	10.17	
Cane fields	Hectares	0.02	0.21	0.09	1.52	0.87
	Iugera	0.09	0.83	0.36	6.08	
Kitchen gardens	Hectares	0.02	0.59	0.14	2.81	1.61
	Iugera	0.10	2.36	0.56	11.25	
Pasture	Hectares	0.01	2.66	0.23	6.61	3.79
	Iugera	0.06	10.63	0.91	26.43	
Pasture with some woodland or scrub	Hectares	0.08	16.10	2.83	22.64	13.00
	Iugera	0.33	64.39	11.32	90.56	
Meadow	Hectares	0.06	9.51	4.79	9.58	5.50
	Iugera	0.25	38.05	19.15	38.30	
Woodland (some coppiced)	Hectares	0.02	22.19	2.59	57.81	33.19
	Iugera	0.09	88.77	10.36	231.24	

A third of the area was taken up with woodland. This is perhaps unsurprising given the topography of the region. Nepi is situated between two tributaries of the Tiber, and the woodland follows the steep slope of a valley edge. This woodland provided valuable resources in the form of fuel and pannage, whilst the remainder of the area was primarily taken up with wheat growing in conjunction with vines or tree crops (43%). However, the modern land use map showed these areas to have been reduced to scrub, probably as a result of over-exploitation. The mixed nature of farming at Nepi is demonstrated not only by the intercultivation of the various field and tree crops, but also by the presence of large areas of pasture (approximately 100 *iugera*) which are not shown on the modern land use map.

This exercise is important as, rather than the broad classes given by the modern land use map (Figure 4.11, page 154), instead Table 4.14 emphasises under-represented land use types (e.g. viticulture, dedicated pasture, managed woodland) thereby indicating that these types of production could have been more prevalent than is apparent from the smaller resolution dataset. The 19th century cadastral maps provide a more detailed picture of the immediate hinterlands of urban areas at a time before large-scale machine-powered agriculture dominated the study area. Although this cannot tell us what economies were present around urban centres during the Roman period, it does serve to demonstrate the potential of certain economy types, and to provide more detail on the intercultivation of certain crops.

4.7 Identifying woodland areas

Agricultural activities such as arable cultivation are restricted by the presence of woodland, and so some assessment of potential areas is necessary. By the Republican period, a large quantity of the 'primeval' forest is thought to have been cleared for the building of roads, towns, and opening up of areas for agricultural activities (Ward-Perkins 1962: 392, 399). Despite this, some woodland cover remained: indications from literary sources, such as that of Dionysius of Halicarnassus (*Ant. Rom.* 1.37.4), describe Italy as still being well wooded.

> *But most wonderful of all are the forests growing upon the rocky heights, in the glens and on the uncultivated hills, from which the inhabitants are abundantly supplied with fine timber suitable for the building of ships as well as for all other purposes.*

This is backed up to some extent by the data from the lake cores, which, as discussed in Chapter 2, showed large areas to have still retained woodland at this time.

Woodland was exploited not only for fuel and building materials, but could also have been used as pannage for the herding of pigs or for hunting. For example, Columella describes woods as the best feeding grounds for pigs (*Rust*. 7.9.6), and states that woodland can be more profitable than vineyards (*Rust*. 3.3.2). Additionally, the fact that large quantities of wood were required for activities such as industry, heating and baths, we may therefore assume that woodland was regarded by the Romans as a stable and reliable source of income (Rawson 1976: 97).

Nowadays, much of the old forest regions have often been reduced to areas of scrub (see the Nepi example above), and some areas of modern woodland are post-Classical re-growth in different areas. This is known due to the presence of ancient villa and farm remains within wooded areas (Ward-Perkins 1970: 10). We now only roughly know where the original woodland cover was. These areas include the Ciminian forest around the area of Lake Bracciano known from Livy (9.36), and some peripheral areas around Sutri and Nepi as indicated by the environmental evidence (Ward-Perkins 1970: 10-11). The town of *Lucus Feroniae* was named after the presence of a sacred grove (*lucus*) of a Sabine deity, which acted as an attractor for settlement due to the traffic of worshippers and traders (Dyson 1992: 128). The exact location and extent of this woodland, however, is unknown.

The presence of woodland would have precluded the cultivation of any major crops, but, as highlighted above, it was still a valuable source of raw materials, and possibly a source of animal products. It is therefore a worthwhile exercise to postulate areas of potential woodland. Firstly the existing areas of woodland were compared to the known Roman sites to determine which areas may be later re-growth. Twelve Late Republican sites and thirty-two Early Imperial sites are located in what is now woodland. These areas were isolated and it was noted that the sites were, on the whole, located on the periphery of the woodland. This could be interpreted as re-growth of woodland over rural sites originally located near to woodland resources.

The existing woodland known from the modern land use map was then compared to slope and altitude. It was expected that results would indicate that steeper and higher slopes (such as mountains or the sides of valleys) would yield more frequent instances of woodland than flatter areas. This was not so, as results showed that the largest amount of woodland occurred at an altitude of between 100-300 metres above sea level, and appeared to be fairly evenly spread on all slopes (see Tables 4.15 and 4.16). What was noticed however, was that when the observed amount of woodland was compared to the *expected* amount (following the χ^2 test) much less woodland fell on both the lower altitudes and on flatter slopes than would be expected if taking account of the area covered by each category.

Unfortunately these results do not identify patterns significant enough to be able to predict the likely areas of ancient woodland, though visual inspection of the modern land use map (Figure 4.11, page 154) does imply that the majority of upland and steep slopes could have contained a large amount of woodland and forest. Figure 4.10 (page 154) and Figure 4.12

(page 160) highlight the predominance of woodland in these types of areas, particularly the slopes of the river valleys, the areas surrounded the volcanic crater lakes, and the more mountainous regions of the pre-Apennines.

Table 4.15 Woodland compared to altitude

Slope %	Woodland in ha	%	Expected	(O – E)
0-100	2343.06	7.16	6027.97	-3684.91
100-200	7132.77	21.81	9555.25	-2422.48
200-300	5013.63	15.33	7914.09	-2900.46
300-400	3701.79	11.32	3957.69	-255.90
400-500	3887.28	11.88	2363.10	1524.18
500-600	3470.4	10.61	1197.95	2272.45
600-700	2805.84	8.58	739.17	2066.67
700-800	2202.66	6.73	520.80	1681.86
800-900	1150.56	3.52	236.22	914.34
900-1000	479.88	1.47	89.31	390.57
1000-1100	359.1	1.10	69.52	289.58
1100-1200	153.81	0.47	32.09	121.72
1200-1300	10.26	0.03	7.89	2.37

Table 4.16 Woodland compared to slope

Slope %	Woodland in ha	%	Expected	(O – E)
0-3	1685.61	5.15	6576.59	-4890.98
3-6	2187.36	6.69	5563.87	-3376.51
6-9	2350.08	7.18	4256.13	-1906.05
9-12	1794.15	5.48	2658.39	-864.24
12-15	2281.95	6.98	2880.88	-598.93
15-18	2046.51	6.26	2087.66	-41.15
18-21	2057.04	6.29	1725.43	331.61
21-24	1890.9	5.78	1320.29	570.61
24-27	2051.1	6.27	1203.78	847.32
27-30	1899.54	5.81	959.07	940.47
30-33	1880.19	5.75	806.95	1073.24
33-36	1651.77	5.05	605.89	1045.88
36-39	1473.93	4.51	459.32	1014.61
39-42	1232.73	3.77	340.16	892.57
42-45	1239.39	3.79	299.16	940.23
45-48	1055.61	3.23	233.32	822.29
48-51	844.92	2.58	174.95	669.97
51-54	738.9	2.26	141.28	597.62
54-57	566.64	1.73	101.93	464.71
57-60	513.63	1.57	89.32	424.31
60+	1269.09	3.88	226.65	1042.44

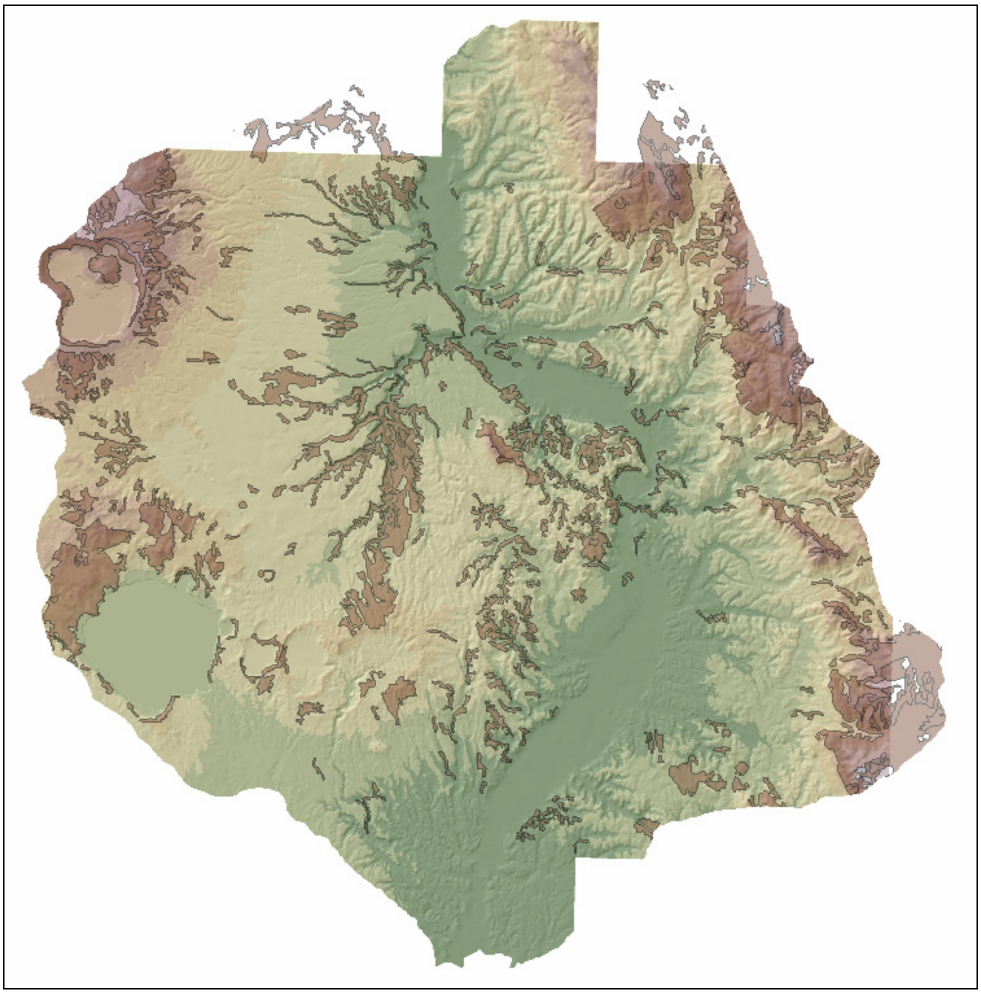


Figure 4.12 Woodland areas overlaid onto the topographical map of the study area (British School at Rome / Comune di Roma)

4.8 The River Systems and geomorphology

Access to water is considered an important factor in the location of sites for agriculture and is necessary for a number of tasks, including the irrigation of crops. Spurr (1986a: 20), however, argues that the annual rainfall in Italy (901.70mm annually in Rome, Naval Intelligence Division 1945a: 533-4, tab. 6) was sufficient to render irrigation unnecessary. This is supported by Wilson (1994) who, using the FAO's CROPWAT system, calculated the amount of water required for such agricultural activities. Based on the average rainfall distribution, he determined that cereals would not need to be irrigated in this area, and this is supported by Pliny the Elder's implication that the irrigation of cereals was unusual (*NH* 17.250 below; see also Spurr 1986: 20).

> *Irrigation is good for trees in the heat of summer but bad for them in winter … [too much irrigation] hurts the roots …those that require most watering are those that have been used to it, whereas those which have sprung up in dry places only need a bare minimum of moisture*
>
> *NH* 17.249

> *…in the Fabii district of the territory of Sulmo in Italy, where they irrigate even the plough land…and irrigation takes the place of a hoe for weeding.*
>
> *NH* 17.250

Tree crops and vines were resistant to drought, and so required little irrigation. Horticulture and pastures, however, would have required extensive irrigation (Wilson 1994: 158-163). However, this does not take into account the required water supply for human and animal consumption. Also, access to navigable rivers was important for transport of people and commodities.

Work carried out in South Etruria has highlighted the presence of a number of water sources and man-made hydraulic structures from the Roman and Etruscan periods (Wilson 1994). Although generally the annual rainfall was likely to have been sufficient for agriculture, water was collected for domestic and other uses through a variety of systems. These included roof runoff systems, surface water runoff, and ground water storage, as well as water supplied by aqueduct systems and other conduits (Wilson 1994: 140-150).

Within the study area, at *Lucus Feroniae*, we know that the town aqueduct, the *Aqua Augusta*, was supplied by a nearby river. This river was later the site of two medieval mills (Jones

1962: 197-199). Further north near Corchiano are the remains of two small dams that diverted water from a nearby river (Quilici-Gigli 1989: 127; in Wilson 1994: 141-142). On the basis of this and epigraphic evidence, Wilson concluded that aqueduct and conduit systems were fairly common in rural areas such as this. Springs and other ground water sources were also utilised frequently within the study area. It was noted that many Roman villas and farms were situated near both major and minor springs (Wilson 1994: 145-146). Near Sutri and Lago di Bracciano, in the west of the study area, his research has identified between 0.5 and 1.3 springs per square kilometre.

Looking at the digital coverage of the stream and river network, it seems that this area is extremely well served, even without the added water sources of springs, aqueducts and collected rainwater. A water supply would therefore seem to have been readily available to the majority of settlers, rather than the preserve of the few. Morley, however, highlights the competition between the city of Rome and its hinterland for their water supply (Morley 1996: 104). A large amount of water was likely to have been carried via aqueducts for consumption in the city for luxuries such as baths and fountains: baths, in particular, require large quantities of water (Hodge 1992: 49). The irrigation needs of horticulture, which was likely to have been common in the areas surrounding the city, would also have been in direct competition with local agricultural needs.

It has been calculated that irrigation of as small an area as one square kilometre with 20mm of water would have used the equivalent of the entire daily output of a medium sized Roman city aqueduct, around 20,000m^3 (Hodge 1992: 247). Many people, however, would still have relied on wells and cisterns for personal water usage and so it would be very difficult to quantify explicitly the water usage of Rome and the effect on the water supply of the rural hinterland.

A site's proximity to a water sources was consequently of great importance, depending on the economy followed. Also, the domestic demands of both humans and animals would have required a regular supply. It has been stated that the water requirements of cattle are nineteen litres per day, and five litres for donkeys (Pallas 1986; in Wilson 1994: 163 n.98). Humans require a minimum of five litres per day for consumption and household usage. For small farms this requirement would probably have been met by small springs or roof runoff (Wilson 1994: 170-171).

That which was not supplied by collection strategies such as this, or from cisterns or wells would have been supplied via the rivers. The map of the river system available from the Tiber Valley Project comprises both major and minor rivers. These were used to create Euclidean distance maps. This showed how far each pixel of the map was away from a river. These maps were then reclassified into 100 metre corridors (Figure 4.13). The Roman sites were then compared to this reclassified map to see if they were located near rivers. This has its problems, of course, as the river network, as well as the Tiber itself, is known to have changed course to some extent. Rivers are not stable features, and so there is every possibility that the modern system will not reflect exactly the situation in the Roman period. Results from this analysis must therefore be treated with caution. However, river migration within this type of topography generally stays within the confines of the valley system and so some quantification of general distances between the rivers and sites in relation to the existing network will still be of use. Tables 4.17 and 4.18 show that the vast majority of sites are situated within 500 metres of a major or minor river system. Only one site lay further than a kilometre from a river system.

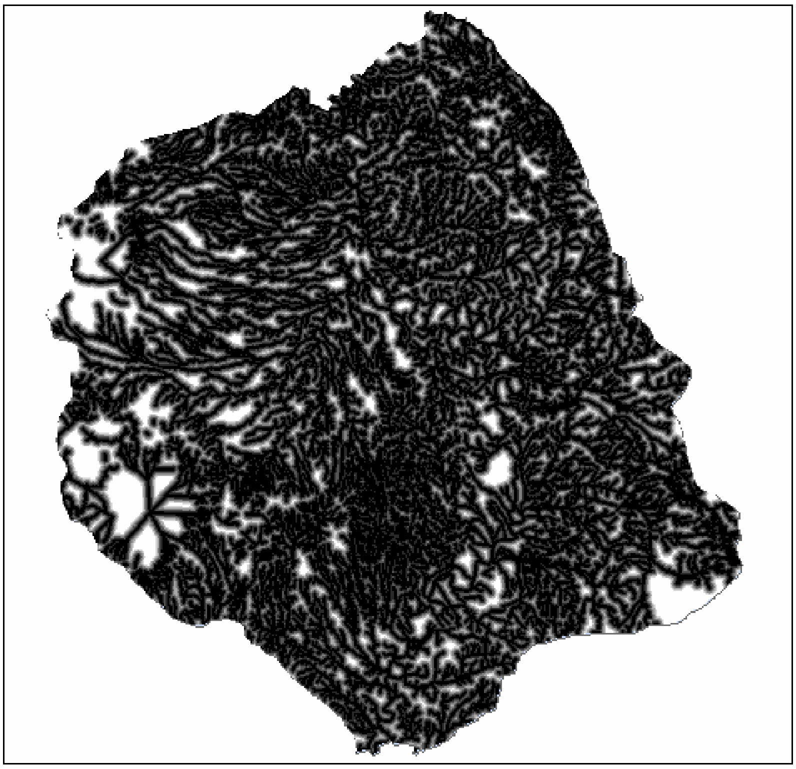


Figure 4.13 Major and minor river network with 100 metre buffers

Table 4.17 Distance of Late Republican and Early Imperial sites from major and minor river systems, plus lakes

Distance from river in metres	Number of sites in this category			
	LR farms	LR villas	EI farms	EI villas
1-100	39	75	148	184
100-200	65	127	213	271
200-300	42	67	150	149
300-400	17	33	41	71
400-500	2	8	21	23
500-600	1	9	5	18
600-700	3	2	4	4
700-800		1	5	2
800-900			2	
900-1000			1	

Table 4.18 Percentage of sites within certain distances of rivers and lakes

	LR farms	LR villas	EI farms	EI villas
100m	23.08	23.29	25.08	25.48
500m	97.63	96.27	97.12	96.68
1000m	100	100	100	100

As irrigation and subsistence were not the only uses for water, the major river systems, which were likely to have been navigable, were then assessed to see if sites were located nearby. The results from Table 4.19 show that approximately half of the sites were located within 500 metres of a major river system. It was also noted that there is no discernible difference between the location of farms and villas in the two periods, though villas were located very slightly closer on average (Table 4.20).

Table 4.19 Cumulative percentage of sites within certain distances of major rivers and lakes (see Appendix III, Table III.12 for full results)

	LR farms	LR villas	EI farms	EI villas
100m	6.40	2.75	6.21	3.68
500m	50.00	53.21	51.85	51.63
1000m	76.16	84.71	78.86	79.84
1500m	89.53	93.58	90.94	92.37
2000m	96.51	98.78	96.31	98.37
2500m	98.84	99.69	99.16	99.59
3000m	100	100	100	100

Table 4.20 Chi-squared test on distance from river

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	610.6m	639.65	17.53	$\alpha = 0.1$	19.81	13	NO
LR villas		566.97	45.80	$\alpha = 0.001$	34.53		YES
EI farms		635.02	35.13	$\alpha = 0.001$	34.53		YES
EI villas		596.42	55.67	$\alpha = 0.001$	34.53		YES

As stated previously, rivers are not stable entities and so this factor must be treated with caution. According to geomorphological work in the river valley, streams in this area were laterally mobile, necessitating the construction of large viaducts (such as that over the River Treia discussed previously) rather than simple bridges. However, they seem to have moved within the constraints of the valleys and so distance to sites would not be radically affected (Brown and Ellis 1995). As sites did indeed seem to lie close to the existing river network (Table 4.20 indicates that they are mostly around 560-640m away), this was not considered to be a major problem within the analysis. The distance from major rivers only was therefore used in further models, given the variability of smaller tributaries. This was therefore used as a variable to indicate transport routes rather than water supply.

4.9 The Roman Roads of the Tiber Valley

Roman roads are numerous within the study area. Aside from the major roads – the Viae Flaminia, Salaria, Nomentana, Tiberina, Amerina, Cassia and Clodia – are a number of smaller unpaved roads and trackways that run throughout the landscape. Distance to roads has been cited as a settlement attractor - "*near it there should be … a good and much travelled road*" (Cato *de Agr*. 1.3-4). This has also been noted archaeologically, for example the shift in settlement focus in the *ager Veientanus* towards the new consular road (Ward-Perkins 1962: 397-398). The cost of transport by road, however, has been maintained to have been overly costly for the average peasant farmer on the basis of evidence from the Edict of Diocletian, amounting to 55% of the wheat's value per 100 miles (Duncan-Jones 1982: 366-369). However, we know that roads were used for agricultural traffic. If this were not the case, we would not hear of such activities as described by Varro whereby mule trains brought wine, olive oil and cereals from Apulia to the ports on the Adriatic coast:

> *…but there really are no herds of [mules] except of those which form pack trains … The trains are usually formed by the traders, as, for instance, those who pack oil or wine and grain or other products from the region of Brundisium or Apulia to the sea in donkey panniers"*
>
> Varro *Rust*. 2.6.5

Whether the charges applied only to the major consular roads is unknown. This could have important implications for local transport and the use of smaller road networks.

Laurence (1999) also argued the case for road use. The repair of roads by Augustus, and his encouragement to other senators to follow his example (Suet. *Aug.* 30) was noted as one supporting factor. Water transport, though arguably cheaper than road, would not have been available or convenient for all farmers in the study area and, even if going by river, farmers would still need to use roads to transport goods from their farm or estate to the Tiber. Even though it was the more expensive option does not mean that it did not occur (Laurence 1999: 42, 95-107).

De Neeve (1984: 25) noted in his locational study of the area of Veii that the majority of sites were located near the lines of communication. Some villas in the area even built their own roads. Small farms, he believed, were located further from these networks. What De Neeve lacks, however, is an absolute quantification of the actual distances involved. The distance from sites to roads was therefore analysed in the same way as that of the rivers. Two maps were created for the Roman roads in the area showing paved and unpaved roads. For the paved road coverage, those definitely paved, and those 'probably' paved were grouped together. For the unpaved road coverage, those known to have been unpaved, and those classed as 'unknown' were grouped together. The roads have not, unfortunately, been dated any closer than to the Roman period. This means that not all roads used within the analysis will necessarily have been in use at the same time. The nature of roads, however, are that paved roads often follow pre-existing courses, which means that slightly later paved roads may have existed, for example, as trackways previously.

A Euclidean distance map was created for each of the coverages, and these were again divided into 100 metre corridors (Figure 4.14). The number of sites falling in these corridors were noted, and these are summarised in Tables 4.21 and 4.22.

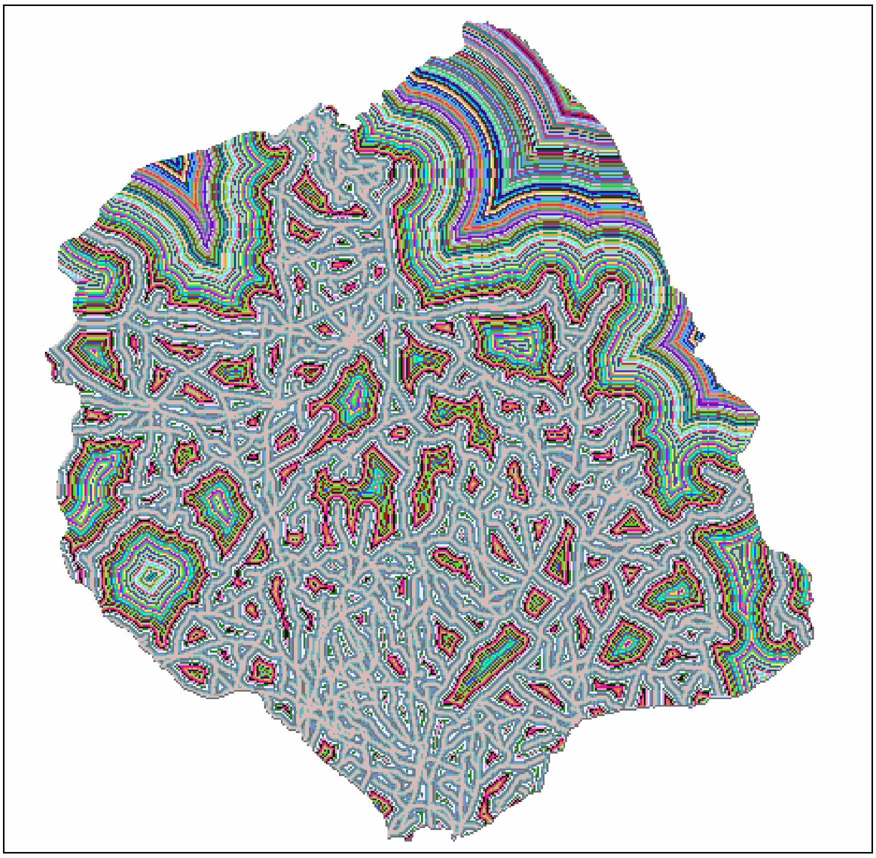


Figure 4.14 Road network showing 100 metre corridors

Table 4.21 Cumulative percentage of sites within certain distances from paved and unpaved roads

	LR farms	LR villas	EI farms	EI villas
100m	18.01	29.58	23.13	27.40
500m	73.29	81.35	71.35	79.05
1000m	91.93	96.78	92.53	94.84
1500m	98.14	99.04	97.86	97.85
2000m	100	99.36	99.47	98.71
2500m		99.68	99.64	99.14
3000m		100	99.82	99.28
3500m			100	99.57
8000m				100

Table 4.22 Cumulative percentage of sites within certain distances from paved roads only

	LR farms	LR villas	EI farms	EI villas
100m	5.45	14.60	8.03	12.48
500m	30.91	38.82	33.68	40.67
1000m	58.79	58.39	60.21	61.43
1500m	78.79	77.95	76.79	77.70
2000m	85.45	85.71	86.04	86.26
2500m	92.73	90.06	91.62	90.04
3000m	95.15	93.79	95.46	93.83
3500m	96.97	96.58	97.56	96.07
4000m	97.58	97.52	98.25	97.34
4500m	98.18	98.14	98.78	98.04
5000m	99.39	98.45	99.65	98.60
5500m	100	99.07	99.83	99.02
7500m		100	99.83	99.86
8000m			100	100

As stated by De Neeve, a larger percentage of villas were indeed located nearer to roads than smaller farms though, as with the river results, this is unlikely to be statistically significant given the very slight difference in figures. According to the results above, between 71 and

81% of all rural sites were located within 500 metres of *any* road system, and between 92 and 97% within a kilometre. Looking at paved roads only, still between 90-93% of sites were situated within 2,500m. This highlights how dense a network existed at this time, and that sites often seem to have been located with transport in mind.

Table 4.23 Chi-squared test on distance from all roads

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	538.84 m	366.99	12.44	$\alpha = 0.1$	21.06	14	NO
LR villas		285.43	95.08	$\alpha = 0.001$	36.12		YES
EI farms		377.04	44.34	$\alpha = 0.001$	36.12		YES
EI villas		338.99	149.64	$\alpha = 0.001$	36.12		YES

Table 4.24 Chi-squared test on distance from paved roads

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	1323.01 m	1060.92	22.67	$\alpha = 0.1$	21.06	14	YES
LR villas		1044.29	46.76	$\alpha = 0.001$	36.12		YES
EI farms		1051.8	41.30	$\alpha = 0.001$	36.12		YES
EI villas		1020.36	83.75	$\alpha = 0.001$	36.12		YES

Chi-squared analysis (Table 4.23 and 4.24) showed the same pattern, with sites located much closer to all types of road than suggested by the background mean. The distance of Late Republican farms from roads was not statistically significant in Table 4.23, but the remaining categories of site were all shown to have been significantly located, with villas showing more significance than farms. This analysis supports De Neeve's arguments as well as the evidence from the agronomists stating that transport routes were desirable factors in farm and estate location.

4.10 Distance to towns and other nucleated centres

Distance to towns was another factor considered important by the agronomists. Cato, for example, stated that when choosing the site for an estate that "*near it there should be a flourishing town*" (*de Agr*. 1.3). With this in mind a digital coverage of urban centres was created from the site database. This did not merely consist of towns. Also included were a variety of settlement types including *vici*, road stations, villages, and other nucleated settlements that may have acted as markets for local produce. Analysis was therefore carried out on two data sets: the first was on towns only, and the second on all types of nucleated centre from the database.

Periodic markets and fairs were held in the 1st century AD, although it has been suggested that these were gradually superseded by highly urbanised centres (particularly Rome) with permanent exchange mechanisms (de Ligt 1993: 26, 51). Both the periodic and permanent markets stimulated local and regional exchange. This enabled the rural population to acquire necessities in exchange for surplus. More urbanised centres also had a 'central place' function, providing the opportunity to acquire more prestige items generally unavailable to the rural population (de Ligt 1993: 6-7).

Table 4.25 Cumulative percentage of sites within certain distances of all nucleated centres

	LR farms	LR villas	EI farms	EI villas
1 km	1.74	3.51	3.50	6.81
5 km	45.93	35.36	70.17	69.62
10 km	96.51	97.19	99.50	99.18
15 km	100	99.77	99.83	99.73
20 km		100	100	100

Analysis showed that the vast majority of Roman rural sites are located within ten kilometres of an urban centre or nucleated site, thus illustrating the density of urbanism within the study area (Table 4.25). Only scattered sites lay further away than this, with the maximum being 17.5km away. The higher number of sites close to an urban centre in the Early Imperial period partly reflects the higher density of sites, but also the increased number of nucleated centres in this period. Comparing farms and villas we can see that only 2-4% of farms are located within a kilometre of an urban centre, as opposed to 4-7% of villas. Chi-squared analysis (Tables 4.26 and 4.27) showed that Early Imperial villas, in particular, showed preference of location in proximity to towns or other nucleated centres.

Table 4.26 Chi-squared test on distance from towns only

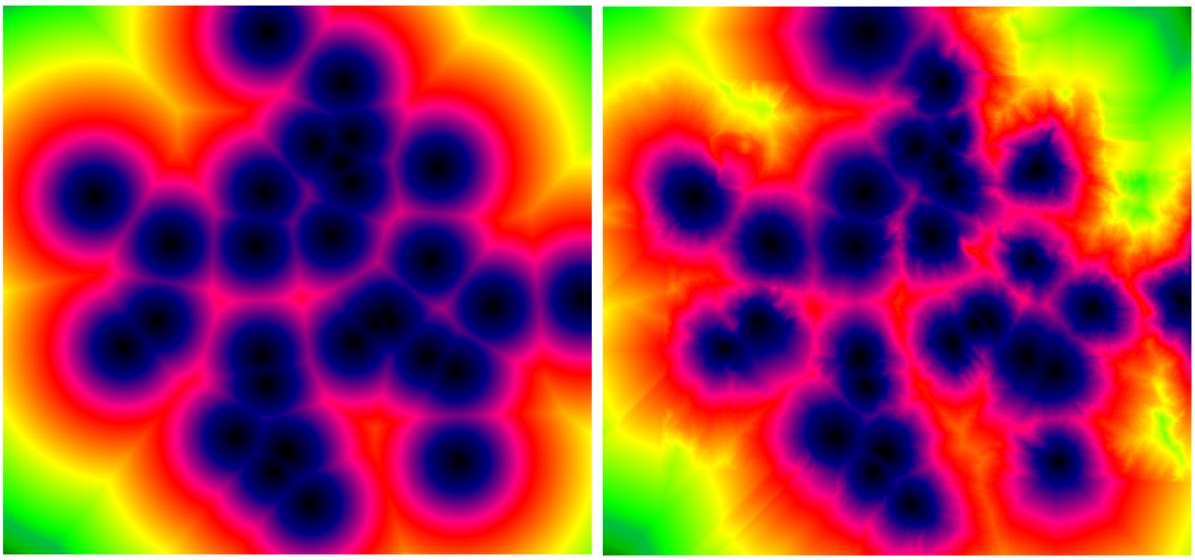
Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	6292.70m	5874.67	14.99	$\alpha = 0.1$	19.81	13	NO
LR villas		5806.66	18.03	$\alpha = 0.1$	19.81		NO
EI farms	5783.36m	5675.87	55.74	$\alpha = 0.001$	34.53		YES
EI villas		5309.03	58.86	$\alpha = 0.001$	34.53		YES

Table 4.27 Chi-squared test on distance from all nucleated centres

Site type	Background mean	Site mean	χ^2	Significance level	χ^2 critical value	Degrees of freedom	Significant?
LR farms	4668.19m	5007.71	33.38	$\alpha = 0.005$	30.82	13	YES
LR villas		4819.43	75.54	$\alpha = 0.001$	34.53		YES
EI farms	3951.68m	3951.15	407.79	$\alpha = 0.001$	34.53		YES
EI villas		3531.43	680.22	$\alpha = 0.001$	34.53		YES

However, again we are dealing with the comparison of two types of site that are not equally visible archaeologically. It may be that this smaller number of farms nearer the centres reflects, not their absence, but an absence of visible archaeological remains. This highlights that immediate proximity may not have been an issue for Roman farmers. As sites are fairly evenly distributed between towns we may infer that the network of urbanisation was such that the whole study area had easy access to one or more centres.

The calculations performed above all assume a flat surface and so, as the terrain is variable, it was decided to convert this into the energy equivalent of walking select distances (measured in kJ) to compare the results. Energy equivalents in kilojoules were estimated by creating a cost surface using no friction and overlaying this with buffers of differing distances (e.g. 1km, 5km, 10km, etc). The cost surface using the terrain as friction was then reclassified according to these energy equivalents to create buffers of distance equivalents (Figure 4.15 and Table 4.28).



a. **b.**

Figure 4.15 Comparison of a) Euclidean and b) cost distances from Early Imperial towns

Table 4.28 Cumulative percentage of sites using cost equivalents

Energy equivalent of distance	LR farms	LR villas	EI farms	EI villas
1 km	1.16	4.23	1.33	4.86
5 km	25.00	28.40	38.67	46.56
10 km	67.44	74.32	90.33	91.23
15 km	97.67	98.49	99.83	99.19
20 km	100	100	100	99.87
25 km				100

The most obvious effect this has on the model is to increase the effort it requires to travel from rural sites to urban centres. This is to be expected. The effort required for the least proximate site is the equivalent of walking up to 25 kilometres on a flat surface, rather than 20 kilometres from the original calculation. With the flat model between 97-100% of sites lay a distance of 10 kilometres away from a town or nucleated centre. This was dramatically reduced to between 67-91% of sites within the equivalent of 10 kilometres. However, given that the maximum distance travelled only increased from 20 to 25 kilometres, i.e. we may still argue that all sites enjoyed good access to urban centres and the services provided therein.

From this analysis we can see that the urban network is such that rural sites may be dispersed evenly throughout the countryside, yet still have a comparable amount of access to the urban resources. The low number of sites (between 1-7%) in direct proximity to urban centres, i.e. within one kilometre, could be due to a number of factors. These include survey collection problems, and the fact that modern suburbs of towns would now cover many areas previously available for ancient settlement. Aside from this, an historical explanation could be that inhabitants of these towns may have exploited the suburban areas, but lived in the centre itself. Alternatively, the suburban areas surrounding towns and cities, although cultivated by small farmers and urban residents in some cases, could have been used for industries unsafe to be contained within the city. Towns were, after all, important as centres for industry, religious worship, political activity, administration and entertainment, and did not merely act as a market for agricultural and animal products (Dyson 1992: 153-156).

4.11 Further regional analysis

As stated previously, there are problems with attempting regional comparisons due to the sample of sites being heavily biased towards South Etruria. However, analysis was attempted regardless in order to ascertain whether any patterns were evident despite the small sample. In many case there was simply not enough data, although some factors showed some minor regional differences.

A brief analysis showed there to have been similar trends to the overall analysis in both modern arable, and in Late Republican and Early Imperial land exploitation in relation to slope. It is hoped that a greater sample from the Sabina region might show more meaningful patterns. Comparisons between farms and villas were also carried out. This was done only on the Early Imperial sample from South Etruria, as this was the largest. Results shown in Figure 4.16 shows similar trends to the original analysis, with farms and villas occupying comparable slopes, except in the case of 15-18% slopes when there is a sudden drop in villas.

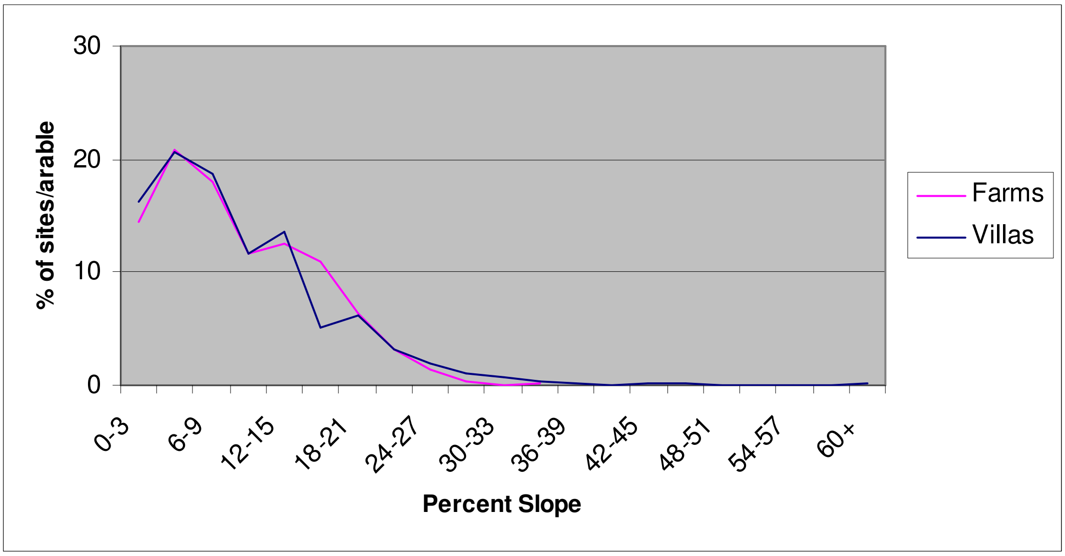


Figure 4.16 Comparison of Early Imperial farms and villas in relation to slope

Regional analysis of aspect and altitude were not possible due to sample size, and no meaningful results were obtained. For urban centres, sites from both regions were all within 10 kilometres of a centre, although for the Sabina, 85-97% of sites were within 5km as opposed to 67-70% for Etruria. For distance to water sources, in general the Sabine sites were closer than those in South Etruria, but again the sample size means that this is not statistically significant. The road coverage is also problematic as there is not a full dataset available for the study area, and the area most lacking is the Sabine region.

All in all, these results were too problematic to show any real regional patterns, though it is hoped that once more field survey has been carried out to fill in a gaps in the Sabine region, more data will show up differences in site location in relation to resources.

4.12 Conclusions

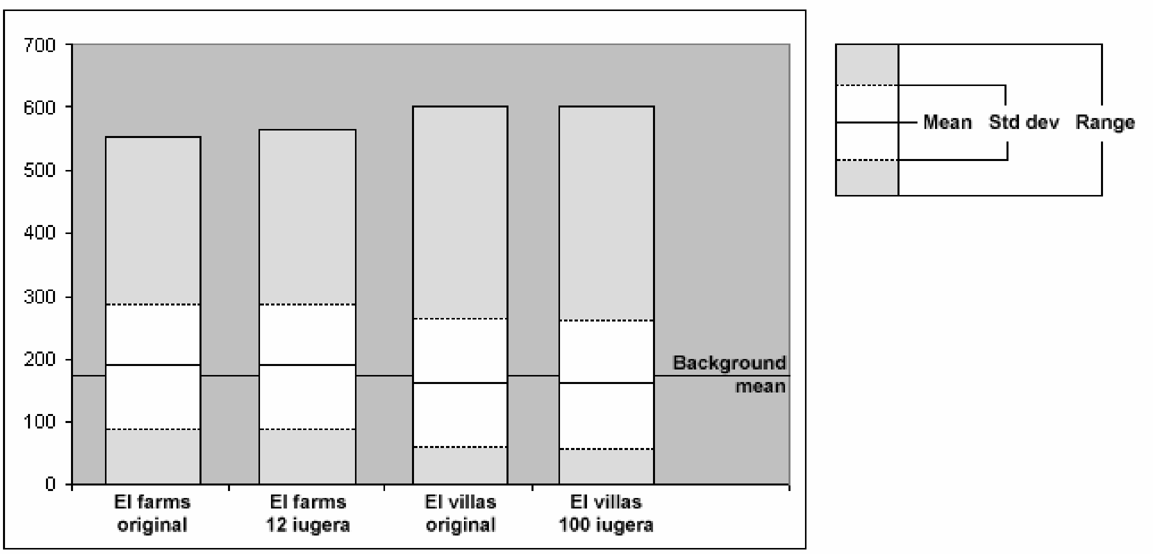
Locational analysis for the entire area has shown in this chapter that Roman rural sites tended to cluster on resources similar to those of today, but with a few key differences, most notably the difference in aspect. South-facing slopes were preferred in the Late Republican period, whilst south-east and east-facing were preferred for Early Imperial sites and modern arable. There were also some slight differences in the use of the underlying geology, with fewer sites using the heavy alluvial soils of the river valley than modern cultivation. Other than this, Roman agriculture, it seems, followed similar patterns as modern cultivation with arable concentrated on volcanic soils and olive cultivation focussed on limestones and sands. Topographic factors also played a part in site location, as results show preference for flatter slopes and low altitudes.

It has been shown in the analysis above that the vast majority of sites seem to conform to at least *some* of the stipulations outlined by the agronomists for optimal site location. Chi-squared analysis showed many instances of preferential location, particularly in the case of social factors such as distance to a road network. Nearly all tests showed that sites were situated on resources more suitable than the background mean of the whole surveyed area. In the majority of analyses the Early Imperial coverage showed the most significant patterning, probably as this was the largest data set. The data generally followed the pattern that farms were located near preferred resources, but that villas were situated on slightly more suitable land than farms. This could either reflect a real differentiation in land access to richer sites, or merely be a reflection of site visibility.

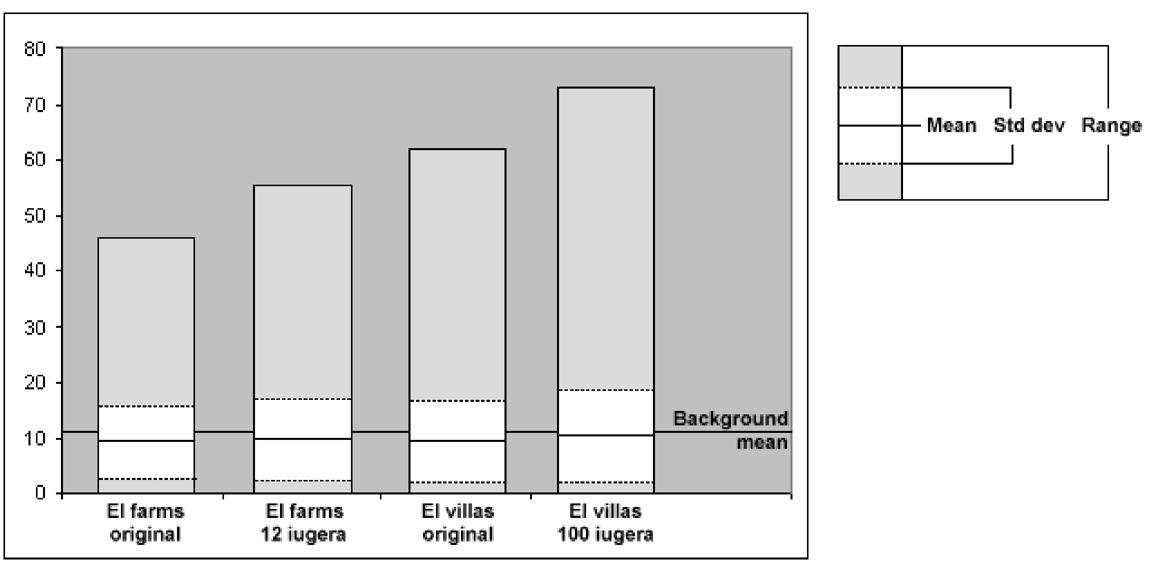
The analysis carried out in this chapter has some limitations, as they refer only to a small central area of what was probably a much larger exploited territory. The process analyses the cell where the site is situated, in this case the cell has a 30m resolution (a 'territory' of only 900m^2 or 0.4 *iugera*). It may therefore follow that the point at which the site is located has different land qualities than nearby areas which may be exploited. An analysis of altitude and slope was therefore carried out on farms of 12 *iugera* and villas of 100 *iugera* (see Chapter 8 for further work on these unit sizes), and then compared to the previous results (Table 4.29).

Table 4.29 Comparison of original analysis and territory analysis on altitude and slope

	Site type	Background mean	Site mean	Min	Max	Std dev
Altitude	EI farms original	174.37m asl	188.28	0	554	100
	EI farms 12 iugera	174.37m asl	187.56	0	565	100
	EI villa original	174.37m asl	161.56	0	601	100
	EI villas 100 iugera	174.37m asl	159.45	0	601	101
Slope	EI farms original	11.24%	9.11	0	46	6.5
	EI farms 12 iugera	11.24%	9.56	0	55	7.2
	EI villas original	11.24%	9.19	0	62	7.4
	EI villas 100 iugera	11.24%	10.23	0	73	8.4



a.



b.

Figure 4.17 Comparison of locational results for original analysis and territories for a) altitude and b) slope

Figure 4.17 shows very little difference in results between the original 'singe-cell analysis' and the larger territory analysis. The mean results and standard deviations vary only slightly, still following the same overall patterns, even though the range of exploited land types expands in both cases, more dramatically with slope than altitude. This highlights that larger territories are exploiting a variety of land use types, yet still with an emphasis on those factors deemed suitable by the agronomists.

The next stage in the analysis is to use the factors assessed in this chapter in order to create maps that highlight those parts of the study area most suitable for different types of agriculture under these conditions. We may then compare the known site distribution to investigate ideas of potential economy or subsistence strategy.

5 THE EVALUATION OF RESOURCES

In Chapter 4 it was assessed where the Roman rural sites were *actually* located in relation to resources, and then compared to the desirable factors as stipulated by the agronomists. This analysis looked at the location of the central site only rather than the resources within its entire territory. This chapter, in an alternative analysis, approaches such an analysis from a different angle. Here the whole landscape is assessed according to stipulations from ancient sources, and these desirable factors are modelled to highlight the areas that conform most. These areas are then compared to the location of known Roman sites. The known sites are overlaid onto the 'predictive' map to see if they are following similar rules to those laid out in the literature and choosing the overall most suitable areas for settlement.

5.1 Land evaluation techniques

Land evaluation techniques have been in existence since the 1970s, but have only recently been applied to archaeological landscapes with applications in places such as Iran (Farshad 1997; 2002), Spain (Verhagen *et al.* 1999), and Italy (see Finke *et al.* 1994; van Joolen 2003; Kamermans 2004). The FAO outlined the methodology, which is typically applied to modern landscapes, in order to ascertain land performance and suitability for different types of agriculture (FAO 1976). The central analysis compares the requirements of different types of land use with the resources available. Essentially, this is performing a suitability classification based around similar precepts as multi-criteria evaluation (See Section 5.2), but with the incorporation of palaeoecological factors such as climate, soils and vegetation, along with economic and social analysis (FAO 1976: section 1.1).

The stages of analysis in archaeological land evaluation are outlined by Kamermans (2004) as follows:

- Create an inventory of the natural environment from field survey
- Construct socio-economic models for early forms of land use from ethnographic, historic and archaeological data
- Classify the area into land mapping units based on physical factors (e.g. topography)
- Carry out a semi-quantitative land classification. Measure the suitability of an area for a certain land use type on the basis of its requirements
- Compare the models of expected land use with the known land use from the archaeological database

Applying this method to archaeological landscapes requires a considerable environmental dataset in order to reconstruct possible land degradation and erosion, as well as carrying out investigations into past climates and gathering evidence on past vegetation (van Joolen 2002: 207-208). This type of approach was not possible with the dataset for the Tiber Valley, but the technique, nonetheless, is of interest and certain aspects were used in my own approach.

Themes to be included in any land evaluation are investigations into the different 'land utilisation types' (LUT) of an area, for example monoculture of cereals on large estates or intercultivation of crops on small farms. These LUTs incorporate the types of crops cultivated, technology used, and size of land holdings, and the economic strategy of the farmer (FAO 1976: section 2.3.1; van Joolen 2002: 185, 187; 2003: 21).

It is necessary to determine the land use requirements for different crops, in order to determine which were the most suitable areas for each. The three classifications used within archaeological land evaluation are as follows:

- ‘Suitable’, whereby the crop can be easily cultivated with no land improvement;
- ‘Slightly limited’, whereby without land improvement such as irrigation or drainage, the yields will be low
- ‘Limited’, where cultivation is problematic and yields are minimal.

The archaeological studies mentioned above are similar to this thesis in their aims, as they are attempting to reconstruct ancient land use and consumption. Verhagen *et al*’s (1999) study of an area in South East Spain was an attempt to create potential land use maps with the aim of integrating various archaeological and historical data concerning diet and cultivation techniques and applying it to a particular geographic area. Data used included a Digital Elevation Model, the geology of the area, distance to rivers, and so on, and were compared to the modern land use map. These results were then used to determine how much land was needed to sustain each settlement. A “relative attractivity index” was created for each type of agriculture along similar lines to the suitability map created later in this chapter. Yields were based on data from Spanish agronomists and the diet based around macro remains from archaeological contexts (in van Joolen 2002: 205).

This approach is therefore attempting to reconstruct not only land use, but also what the Romans perceived to have been important land qualities. This attempt to reconstruct ancient thought is fraught with difficulties but can be deduced, at least in part, from the works of the Roman writers – particularly Columella and Pliny the Elder (Verhagen discussion in van Joolen 2002: 206).

To illustrate the process of applying this method to archaeological landscapes, the methodology of van Joolen (2003) will be discussed, particularly as her study relates to an area of Central Italy near my own study area (the *Agro Pontino*, south of Rome). Factors assessed include soils – the most well suited soils for ancient agriculture in Central Italy were determined as being Luvisols, Vertisols, and Fluvisols. The least suitable are Arenosols, Regosols and Planosols (van Joolen 2003: 27-28). In the same study, slopes were considered for two different scenarios – manual labour and the use of ploughs – and were classified into three categories as shown in Table 4.1.

Table 5.1 Slope suitability (after Van Joolen 2003: 28)

	Manual cultivation	Cultivation with light ploughs
Suitable	0-25%	0-13%
Marginally suitable	25-55%	13-55%
Limited	55-100%	55-100%

The remaining factors used are dependent on the level of technology. Further analysis is also performed on factors such as water run-off hazard, rooting conditions, soil horizons, and soil structure and texture (van Joolen 2003: 28-29). All of the factors discussed above were incorporated into a software called ALES (Automated Land Evaluation System; FAO 1976), and result in a suitability map for different types of land use. Obviously different land uses have different requirements. The major utilisation types for Roman Central Italy were determined to be small subsistence farms, isolated larger farms practising self-sufficient mixed farming with some market goods, intercropping of cereals with olives or vines, large *latifundia*-type estates cultivating cash-crops, and slash and burn systems in remote areas (van Joolen 2003: 121, 135).

The results of this study indicated the most appropriate land use for a number of different periods from the Bronze Age onwards. Roman land use included marginal cereal farming in most of the study area with some olive and vine cultivation in certain areas. These hypotheses were compared to field survey data for site location and site type. Results indicated some correlation with presence/absence of site and suitability for production, as well as using artefacts to indicate production strategy to compare with the most suitable land use as predicted (van Joolen 2003: 183).

Although land evaluation is a very useful tool for gaining insights into aspects of ancient agricultural production, there are of course problems with this sort of approach. Firstly it requires specialist software. Methodological issues are also problematic, and a number of assumptions are required to carry out such analyses (Kamermans 2004).

- Man exploited the environment according to the principle of least effort (Zipf 1949)
- The combination of environment and human behaviour creates a specific spatial pattern in particular types of areas
- There is a relationship between prehistoric land use and artefact density
- The economic system during each period was constant

An additional problem with the Roman period is that we must look to the ancient sources for evidence for both land utilisation types and land use requirements in this period. One must not look at landscapes from a modern point of view, as what we now consider to be good criteria for agriculture are not necessarily the same as those in antiquity. The "human perception of suitability" has changed over the years (Verhagen 2002: 202). The Roman perception of suitability may be studied via the texts of the Roman agronomists to analyse any differences from the modern perception (Favory *et al.* 1995; in Verhagen 2002: 202). These texts seem to favour the use of light, easily workable soils. Workability, indeed, rather than fertility, has been argued to have been the overriding factor in soil choice (Verhagen 2002: 203). Factors incorporated into a classification of workability are therefore slope percentage, surface stoniness, rockiness, texture (i.e. clay type, whether loose or firm), and soil consistency (i.e. loose, friable, firm) (Farshad discussion in van Joolen 2002: 206). Also, improved technology may increase a soil's workability as, for example, a better plough would make heavier soils more easily cultivable (van Joolen 2002: 207).

Land evaluation is a useful approach to determine the most suitable kind of land use in a specific context but, as stated previously, the Tiber Valley dataset lacks much of the required environmental information. However, many of the factors used by such archaeological studies may be transferred to an alternative method. Multi-criteria evaluation, one of the methods used in archaeological predictive modelling, is therefore discussed below as an alternative technique.

5.2 Multi-criteria evaluation

Lacking the specialist ALES software along with some of the key data sets (e.g. soil) meant that an alternative approach was required for assessing land suitability for different types of agriculture. A different method was devised, incorporating some of these methods, using the technique of multi-criteria evaluation (MCE) to define suitability for different agricultural strategies.

Multi-criteria evaluation is just one of many methods used in archaeological predictive modelling. Predictive modelling is a common approach used in landscape study and is primarily used to identify areas of archaeological sensitivity (areas likely to contain sites) based on known site characteristics, and as a technique has come in for criticism on a number of methodological levels (e.g. Wheatley 2004). However, the techniques used may also be used in a different way in order to predict areas that are suitable for certain types of activities, e.g. land exploitation strategies (Kamermans 2000). It must be remembered, however, that the end result is merely an indicator of possibility. Predictive models cannot represent the exact situation of all sites in the period under study, but instead are models designed to instigate discussion and present possibilities (Verhagen, discussion in van Leusen 2002: 131).

Decision-making is an important function of GIS, and can facilitate actions such as resource allocation, land evaluation, and so on. It also has the potential for simulating the spatial effects of predicted decision behaviour. As a basic definition,

> *Decision Theory is concerned with the logic by which one arrives at a choice between alternatives*
>
> Eastman 2001: 1

Within this approach are a number of elements, including the objective, criteria, decision rule, and evaluation, as well as the concept of uncertainty (Eastman 2001: 1-5).

Firstly, the objective shapes the nature of one's analysis. In this instance, the objective is to determine the areas most suitable for certain economies in the Roman period. To do this, it is necessary to know both what the requirements of ancient crops were, and what was considered to be good practice at this time. The first is incredibly difficult to determine as such crops are not currently cultivated extensively and in some cases are now genetically changed (e.g. some types of wheat; van Joolen 2002: 187). Certain aspects of the second, however, may be extracted from the literary evidence of the agronomists. From these we may also determine some idea of the crop requirements unavailable from modern sources.

The objective outlined above determines the choice of criteria used within the analysis, and how they are weighted. A criterion is a dataset used within the analysis, and can be one of two types – a factor or constraint. Factors are essentially a measure of suitability of a particular dataset for a particular purpose. It therefore is usually ranked from least to most suitable (in this case a dataset ranked from 0-255). This is similar to the 'requirements' of Land Evaluation, except that the suitability is rated on a numeric scale rather than in the three categories of 'suitable', 'slightly limited', and 'limited' (see Section 5.1).

Constraints, on the other hand, limit the alternatives by excluding certain areas completely, similar to the 'limitations' of Land Evaluation. For example, areas with lakes obviously cannot be cultivated. The constraints are 'Boolean' maps (see below) which can exclude unsuitable areas when maps are combined by multiplication (Eastman 2001: 2-4).

The decision rule determines how these criteria will be analysed. For example, in creating a suitability map for arable agriculture, we might combine various criteria using all factors weighted equally. Alternatively we might assume a ranking of importance for different factors, and use different weights for each one. The results may then be ranked in suitability then limited to the best areas from a specific acreage (e.g. showing the best 10 hectares of an area).

The evaluation itself can be either a multi-*criteria* evaluation, or multi-*objective* evaluation (Eastman 2001: 3). Multi-objective evaluation simply involves an analysis incorporating more than one objective, such as finding areas suitable both for agriculture and pasturage. This technique was not used here. Multi-criteria evaluation, the technique used in this analysis, can work in two ways. The first is using Boolean overlay. This combines binary maps, coded with either 1s or 0s to demonstrate presence/absence, suitable/not suitable, and so on. By using the logical AND operator (Figure 5.1) areas that do not attain every criterion can be excluded.

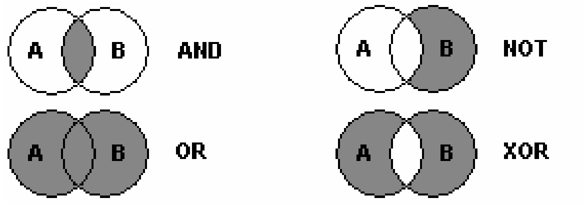


Figure 5.1. Logical operators used in Boolean overlay

The other type of decision making, which has been used in this study, is weighted linear combination (WLC). For this type of analysis, each of the factors must be standardised into a common format from least to most suitable (categorised on a scale from 0-255). These were then given weights according to their relative importance, and combined using a weighted average. Constraints are then overlaid to exclude areas of unsuitability. This means that an area's relative merits will be assessed, rather than be discounted for the absence of one suitable factor (Eastman 2001: 4-5).

If the factors used are of differing importance, rather than using a simple overlay, these may be weighted accordingly within the analysis. The technique for determining weights used within the module is taken from Saaty's *Analytical Hierarchy Process* (Saaty 1977). In this technique, weights are determined by creating a symmetrical matrix with each factor as row and column headings. Each factor is then compared to every other factor and given a rating according to how far it is more or less important, as in Table 5.2 and Figure 5.2. This was decided based on the evidence from the ancient sources, combined with an element of conjecture based on what could be considered the most important factors for Roman farmers (e.g. was ease of work more important than proximity to market?). These weightings are discussed further under each evaluation section.

Table 5.2 Example of a pairwise comparison matrix (the red numbers do not need to appear as they may be calculated from the other half of the matrix)

	Slope	Aspect	Productivity	Dist water	Dist roads	Dist towns
Slope	1	**3**	**1/3**	**3**	**5**	**5**
Aspect	1/3	1	**1/5**	**1**	**3**	**3**
Productivity	3	5	1	**5**	**7**	**7**
Dist water	1/3	1	1/5	1	**1/3**	**1**
Dist roads	1/5	1/3	1/7	3	1	**1**
Dist towns	1/5	1/3	1/7	1	1	1

Less important					More important			
1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely

Figure 5.2 Continuous Rating Scale (after Eastman 2001: 9)

In the matrix above (Table 5.2) it can be seen that the cell that compares 'slope' with 'slope' is coded as 1, as it is obviously of equal importance being the same factor. In the cell directly below this, 'aspect' is compared to 'slope' and is given a code of 1/3. This tells us that aspect is considered to be moderately less important than slope. Below this, 'productivity' is then compared to 'slope' and is classified as 3. This tells us that productivity is moderately more important than slope.

This matrix is then used to create weights for each factor. The weights are derived from the matrix automatically by the GIS, which basically uses the relative importance of each factor to assign a weight: the more important a factor the higher the weight given. As can be seen below, the sum of the weights must always add up to one.

Slope	0.2404
Aspect	0.1123
Productivity	0.4554
Distance to rivers	0.0659
Distance to roads	0.0732
Distance to towns	0.0529
Σ =	1

Figure 5.3 Relative weighting of each factor

The consistency of these entries is automatically assessed. This means that if you do not consistently assign importance within your matrix – for example, if slope was more important than aspect, aspect more important than productivity, but productivity was more important than slope – then the consistency ratio would be classed as unacceptable. In this case the consistency ratio is classed as acceptable at 0.08.

The maps are then multiplied together using these weights, and constraints overlaid to eliminate areas of complete unsuitability. The resulting map is then ranked into order of suitability, again from 0-255, creating the so-called "suitability map". Although classed using a numeric scale, the assessment is essentially qualitative, as it compares the relative suitability of factors. As stated previously, the suitability map is based around the factors considered most suitable by the Roman agronomists, as well as other contemporary data, rather than on modern perceptions of what is suitable (discussed further below). This therefore is not going to give us an accurate land-use map of how things actually were in the Roman period. Instead, a hypothetical map will be created giving the best areas for particular strategies, assuming the Roman agronomists' advice was followed by other farmers. A number of different maps will be created using different criteria and weightings.

5.3 Criteria used for modelling wheat suitability

As an area's suitability for different types of economy will differ, different factor maps were created for use within each multi-criteria evaluation. In line with the methodology outlined above, these were coded from worst to best (0-255) according to their fitness for purpose. As discussed previously, we have a variety of information from both the literary sources and archaeological evidence regarding the suitability of certain types of land for arable agriculture. A number of different models based on this evidence are therefore approached with the aim of investigating further the sorts of criteria used by Roman farmers for site location.

The following evaluations are aiming to predict those areas thought most suitable for agriculture in antiquity according to the ancient evidence. However, it must be remembered when the results are compared with the site data acquired through field survey, that this type of archaeological investigation tends to happen in those areas that were suitable for this type of activity – most notably freshly-ploughed agricultural areas. This does not mean that we are arguing in a circular fashion. Instead it shows that, at least in the surveyed areas, we have a resource with which to support any theories regarding settlement behaviour. Future field investigations could well change this picture.

Firstly, desirable locations for estates were established according to the recommendations of the agronomists. These are not specific to any type of land use, but are useful bases for modelling and can be augmented with crop-specific information. Cato, for example, discusses desirable elements when choosing land to purchase:

> *Notice how the neighbours keep up their places; if the district is good, they should be well kept…It should have a good climate, not subject to storms; the soil should be good, and naturally strong. If possible it should lie at the foot of a mountain and face south; the situation should be healthful, it should be well watered, and near it there should be a flourishing town, or the sea, or a navigable stream, or a good and much travelled road. It should lie among those farms which do not often change owners; where those who have sold farms are sorry to have done do.*
>
> Cato *de Agr*. 1.2-4

Looking at other texts we see similar views. Varro states that grain is better suited to the plains, and quotes Cato's proscriptions for a well-positioned farm (*Rust*. 1.6.5-1.7.2). Columella also refers to Cato in his discussions:

> *But if fortune attends our prayer, we shall have a farm in a healthful climate, with fertile soil, partly level, partly hills with a gentle eastern or southern slope; with some parts of the land cultivated, and other parts wooded and rough; not far from the sea or a navigable stream, by which its products may be carried off and supplies brought in … still these crops thrive better in moderately dry and fertile plains than in steep places, and for that reason even the higher grainfields should have some level sections and should be of as gentle a slope as possible and very much like flat land. Again, other hills should be clad with olive groves and vineyards, and with copses to supply props for the latter … But such a situation as we desire is hard to find and, being uncommon, it falls to the lot of few; the next best is one which possesses most of these qualities, and one is passable which lacks the fewest of them.*
>
> Columella *Rust*. 1.2.3-5

These general statements regarding suitable location may be shown as a table of suitable factors for generic site location (Table 5.3). These factors may then be incorporated with more specific recommendations for particular crops in the following models.

Table 5.3 List of suitable factors for estate location

Factor	Agronomists' recommendations
Fertility	Strong, rich soil
Topography	Plains or gentle slopes
Aspect	South- or east-facing slopes
Water	Close to sea or navigable stream
Town	Close to a town
Road	Close to a road

We cannot know which of these were considered most important by the agronomists. However, as stated previously, some element of conjecture was applied, and Roman farmers were assumed to have prioritised ease of cultivation above social factors such as proximity to transport or markets.

5.3.1 MCE for wheat cultivation: Evaluation One

Factor maps were therefore classified based on these recommendations. The first evaluation applies the recommendations of the agronomists strictly, excluding all those areas not specified. Firstly the slope map was divided into categories to indicate their recommendation of plains or gentle slopes. Plains were considered to be those slopes of between 0-2%, whilst gentle slopes were 2-8%. These two categories were given the highest rating of 255 and all others given progressively lower ratings (Table 5.4). The percentage divisions were decided based on the classifications from the Soil Survey Manual (Soil Survey Division Staff 1993). This gave definitions for each slope type. However, it may be noted from Table 5.5 that these definitions overlap somewhat, and so these were altered to reflect a continuous rating. It must be remembered also, that modern definitions of what constitutes a gentle or moderate slope may not necessarily be the same as ancient conceptions.

Table 5.4 Reclassification for gentle to moderate slopes (after Soil Survey Division Staff 1993: chap. 3, tab. 3.1)

Slope type	Percent slope		Classification
	Soil survey definition	Continuous range	
Nearly level	0-3	0-2	255
Gently sloping / undulating	1-8	2-8	255
Strongly sloping / rolling	4-16	8-13	191
Moderately steep / hilly	10-30	13-25	127
Steep	20-60	25-55	63
Very steep	45+	55+	1

The evidence for aspect had showed south-facing slopes to be preferred (Cato *de Agr*. 1.2) but eastern-facing slopes were also recommended by Columella (*Rust.* 1.2.3). The aspect map was therefore classified to show south-, south-eastern-, and eastern-facing slopes as highly suitable, and all other slopes as unsuitable (Table 5.5).

Table 5.5 Reclassification of aspect to reflect the agronomists' recommendations for wheat

	Classification
North	1
North-East	127
East	255
South-East	255
South	255
South-West	127
West	1
North-West	1
Flat	1

Distance to rivers, roads and centres were then assessed. These were classified to show that the closer one was to a transport route, the more suitable that location would be, though exact quantification of this is difficult as we cannot know what was considered 'near'. To avoid this problem, the cost distance to rivers, roads and urban centres were stretched between 0-255 as a standard scale.

Next, the suitability of land for wheat crops was analysed. It is generally accepted that the genetics of certain crops have altered over the years through the process of domestication and crop selection, making their requirements different to the Roman period crops (e.g. Nesbitt 2001). This is argued to be true for all crops except emmer wheat and the olive, whose requirements may be determined from modern sources (Professor D'Antuono, University of Bologna pers. comm. in van Joolen 2003: 122). The works of the agronomists therefore need to be used to determine the requirements of most crops. There are, however, some problems in using these sources. The ancient writers did not always make clear distinctions between the soils and cultivation needs of cereals and legumes, or between wild and cultivated plants, although they are reasonably clear in most other circumstances (White 1970a: 86-87; Garnsey 1988: 53).

At least six varieties of wheat were cultivated in Central and Southern Italy – emmer wheat (*Triticum dicoccum*), spelt (*Triticum spelta*), einkorn (*Triticum monococcum*), durum wheat (*Triticum durum*), bread wheat (*Triticum aestivum* or *vulgare*) and club wheat (*Triticum compactum*) (Spurr 1986a: 10-17). Emmer wheat (*far*) is believed to have been the most widely cultivated, and had the longest history in cereal cultivation according to the sources (Ovid *Fast*. 2.519-20; 6.180; Pliny the Elder *NH* 18.62; 18.10; 18.84; *Twelve Tables* 3.4). It is also the variety mentioned most frequently by the agronomists (Spurr 1986a: 11-13), and as such is the variety which will be modelled here. The remaining varieties of wheat may not be assessed in this way. The ancient sources do not provide substantial distinctions between requirements for each of these crops, and there is a lack of appropriate modern evidence for comparison.

Emmer wheat is a hardy crop and can be cultivated in marginal areas. Its most suitable soil for cultivation is non-calcareous, fairly fertile, clayey or sandy-clayey soils. When cultivated in very fertile soils, the crop is prone to lodging (whereby the stalk becomes weak and flattens), which means that these more fertile soils may be set aside for other commodities. Emmer wheat also need not be irrigated, weeded or manured in order to produce relatively high yields (Spurr 1986a: 11; van Joolen 2003: 123-124).

> *Grain should be sown in heavy, rich, treeless soil.*
>
> Cato *de Agr.* 6.1

> *Sow spelt preferably in soil that is chalky, or swampy, or red, or humid. Plant wheat in soil that is dry, free from weeds and sunny.*
>
> Cato *de Agr.*34.2

> *Wheat and winter wheat should be sown on high, open ground, where the sun shines longest … spring wheat should be planted in ground in which you cannot ripen the regular variety, or in ground which, because of its strength, does not need to lie fallow*
>
> Cato *de Agr.*35.1

> *In rich soil it is better to plant those requiring more food, as cabbage, wheat, winter wheat and flax*
>
> Varro *Rust*. 1.23.3

> *Grain crops … like dry ground*
>
> Varro *Rust*. 1.23.5

> *Soil which is heavy, rich and treeless should be used for grain*
>
> Varro *Rust*. 1.24.1

> [Grain crops] *thrive better in moderately dry and fertile plains than in steep places*
>
> Columella *Rust*. 1.2.4

Further, every sort of grain especially delights in ground that is open and sloping towards the sun, warm and loose; for though hilly ground produces a somewhat stronger grain, it yields a smaller crop of wheat. Soil that is heavy, chalky and wet is not unsuited to the growing of winter wheat and spelt

Columella *Rust*. 2.9.3

Emmer is the most hardy of every kind and the one that resists winter best. It stands the coldest localities and those that are under-cultivated or extremely hot and dry. It was the first food of the Latium of old times…

Pliny *NH* 18.83-4

No grain is greedier than wheat or draws more nourishment out of the soil.

Pliny *NH* 18.85

As a rule, soil that is black and turns up rich at the pressure,
Of the ploughshare, or crumbling soil (for this we reproduce
By ploughing) is best for corn: no other plain will yield you
So many wagonloads drawn home by the slow-gait oxen.

Virgil *Georg*. 203-206

Spurr (1986a: 38) interprets the agronomists' preferred soils for cereal cultivation as being fertile and easily worked, followed by rich soil that was heavy and clayey. The least suitable soil was dry, stiff and heavy, and infertile. Van Joolen's study of modern wheat production indicated that modern soil requirements were that the soil should be at least 30cm thick, clay or sandy clay, moderately to poorly drained, firmly structured, marginally fertile, and non-calcareous. Marginally suitable soil types are loamy, marshy, fertile, calcareous and of medium salinity, whilst unsuitable types are thin, sandy, excessively drained, loose, very fertile and very calcareous (van Joolen 2003: 124, tab. 4.3).

There are some similarities between the modern methods and the ancient requirements. For example, Cato's suggestion of heavy soil is comparable to the clayey soils of the modern period. However, there are also many differences. Varro's suggestion of dry, rich ground is far removed from the poorly drained and only moderately fertile prescriptions of the modern period. Likewise, nowadays it is not necessary for the ground to be free of weeds, as specified by Cato (see Table 5.8). However, Columella's requirements for winter wheat, specifically, suggests heavy and chalky soil. Although this is preferably dry, it may also be cultivated on wet soil. The interpretation of this passage (*Rust*. 2.9.3) differs in both White and van Joolen's analysis, and is translated as "*heavy, **clayey** and wet*" (my emphasis; van Joolen 2003: 124; White 1970a: 103) which has implications for their perception of soil requirements, as the modern wheat requires non-calcareous soil. The Latin word in question is *cretosaque* and the modern Italian word *cretoso* means chalky.

Returning to the classification of maps for use within the analysis, the level of technology is such that soil texture is not an issue within Roman farming. The development of the plough meant that even heavy soils could be cultivated given the availability of the equipment (see Chapter 2.2.1). It was therefore only necessary to analyse the potential fertility. As there is no usable soil information available, the potential fertility was determined from the underlying geology (see Appendix IV, Table IV.1 for classifications). As the agronomists specified heavy, rich soils the volcanic geology types and alluvial areas were classified as being suitable. As chalky soils were considered acceptable for use, calcareous geology types were given a medium rating. Geology types completely unsuitable for agriculture included areas of rubble and scree. Those types deemed suitable were given a high classification of 255, whilst those unsuitable were classified as 1. Areas of uncertainty or of medium suitability were given a classification of 127. These included the urban areas for which we have no information, as well as areas of sandy deposits that contained concretions, which may have been an obstacle for farming.

The resulting factor map neatly divides into two approximate sections (Figure 5.4a) with most of the potentially very suitable geology types for wheat occurring in South Etruria, and the medium suitability located in the areas close to the Tiber in the Sabine areas. There were very few unsuitable areas. Comparing the map to the modern arable land use (Figure 5.4b), it can be seen that many of the areas cultivated in the modern period overlap with those areas of predicted suitability for wheat, particularly in South Etruria, and following the river valleys. Those areas of the Sabina also cultivated overlap in many places.

For the first evaluation, all the factors (fertility, slope, aspect, distance to rivers, road and towns) were given equal weighting. Constraints were the lakes and the maximum wheat altitude limit from Spurr of 1,200m asl (1986a: 21). Once the module had been run, the resulting map was ranked in suitability with values ranging from 0-255 (Figure 5.5, page 201), and the known sites compared against the suitability rating (Tables 5.6-5.7, page 203). This was run twice, first with the Late Republican urban centres coverage (model 1a), and then with the more extensive urban centres from the Early Imperial period (model 1b).

Figure 5.4 a) Potential fertility map for wheat and b) location of modern arable from the land use map (British School at Rome)

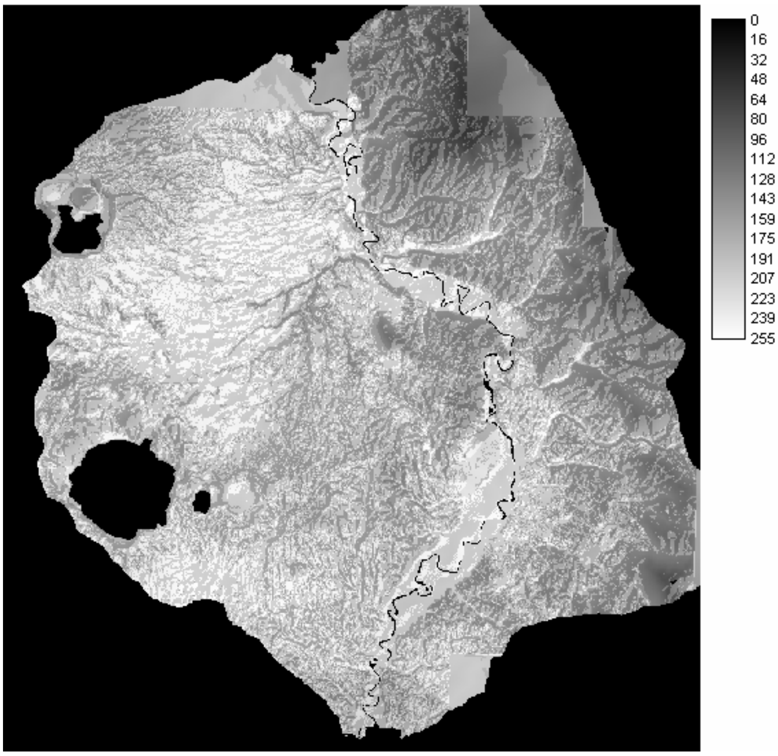


Figure 5.5 Suitability map created using multi-criteria evaluation (Late Republican model 1a)

In order to investigate the distribution of suitable land, a cumulative frequency graph was created and then divided into quartiles and octiles. This essentially divides the suitability distribution into classes of 25% for quartiles and 12.5% for octiles, and serves to highlight which types of suitability are most frequent. The terms 'quartile' and 'octile' refer to the individual value between classes, i.e. in the first evaluation Q_1 (25%) = 169, Q_2 (50%) = 199 and Q_3 (75%) = 221 (see Figure 5.6, the vertical lines indicate the quartile/octile values). Q_2 is therefore also the median value of the whole range of values (Fletcher and Lock 1991: 40-41).

What are of more use in this instance, however, are the ranges *between* these values. I have therefore instead used the term 'quartile range' and 'octile range' to describe these, and they are illustrated as Q_{1-4} and O_{1-8}, as 'true' quartiles are not used in the analysis. To illustrate, in the first evaluation Q_1 = 0-169, Q_2 = 170-199, Q_3 = 200-221 and Q_4 = 221-255 (see Table 5.7). The inter-quartile range is a slightly different measurement, defining the numeric range of each class independently, and this is also included in each table to further illustrate the distribution. As these divisions are standard units (i.e. 25% or 12.5% of the distribution), a low inter-quartile or inter-octile range will show that more of a particular suitability is present in the distribution, and *vice versa*.

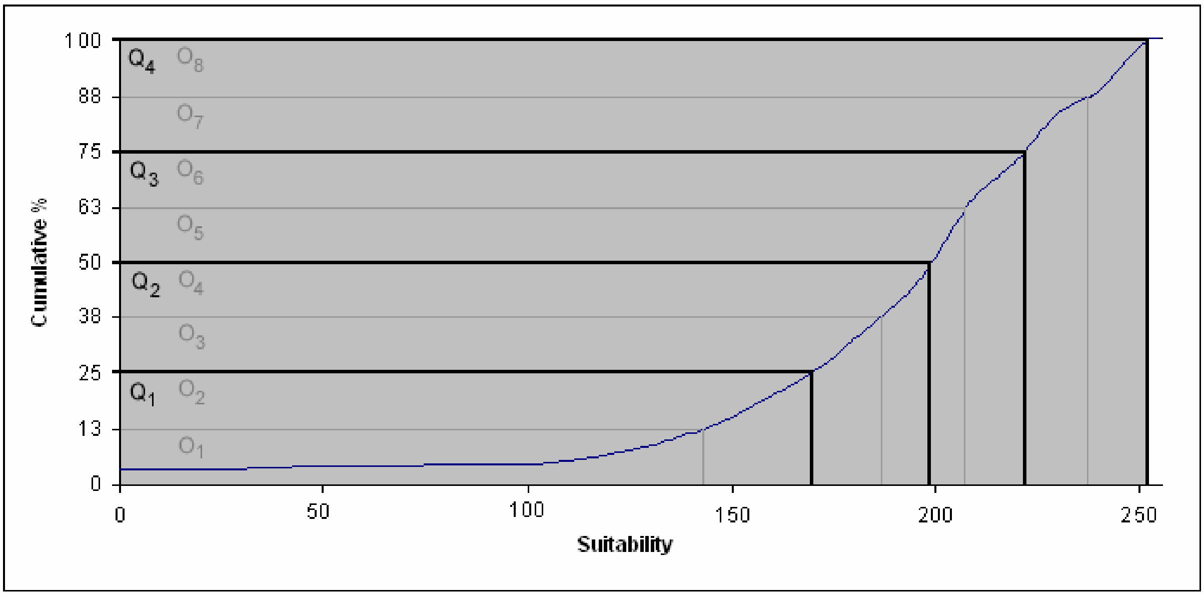


Figure 5.6 Graph showing quartiles and octiles of suitability distribution (Late Republican model 1a)

Dividing the map into quartiles and octiles based on the area covered by each suitability category (Figure 5.6 and Table 5.6) showed also that there is significantly more of the better quality land within the study area, particularly in Q_3, as this is the narrowest band. Dividing it further into octiles (Table 5.7) was less informative, however, though it did emphasise the fact there is there is very little of the worst quality land in the study area (O_1).

Table 5.6 Number of Late Republican sites in each suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	LR farms	LR villas	% LR farms	% LR villas
Q_1	0-169	169	2	13	1.37	4.64
Q_2	170-199	29	39	65	26.71	23.21
Q_3	200-221	21	53	98	36.30	35.00
Q_4	222-255	33	52	104	35.62	37.14

Table 5.7 Number of Late Republican sites in each suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	LR farms	LR villas	% LR farms	% LR villas
O_1	0-142	142	0	2	0.00	0.71
O_2	143-169	26	2	11	1.37	3.93
O_3	170-186	16	29	33	19.86	11.79
O_4	187-199	12	10	32	6.85	11.43
O_5	200-207	7	33	46	22.60	16.43
O_6	208-221	13	20	52	13.70	18.57
O_7	222-238	16	32	47	21.92	16.79
O_8	239-255	16	20	57	13.70	20.36

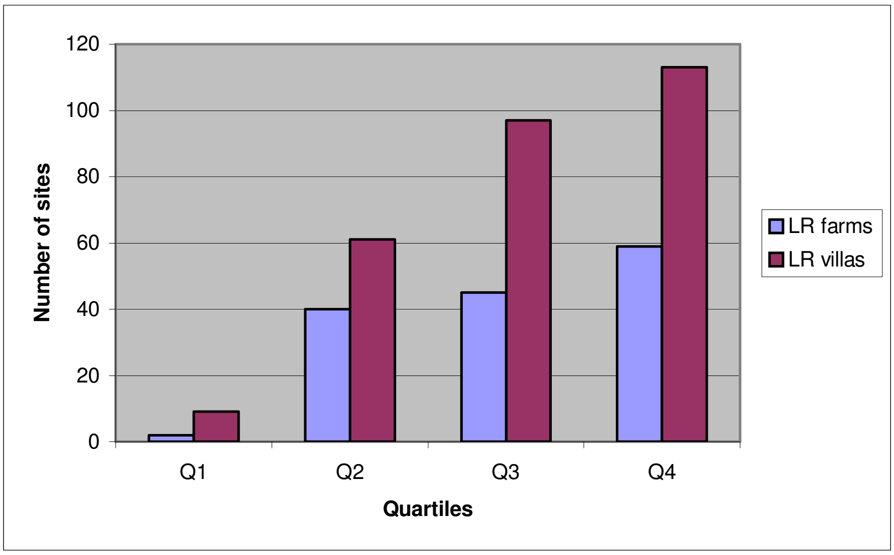


Figure 5.7 Bar chart showing number of sites in each quartile range (Late Republican model 1a)

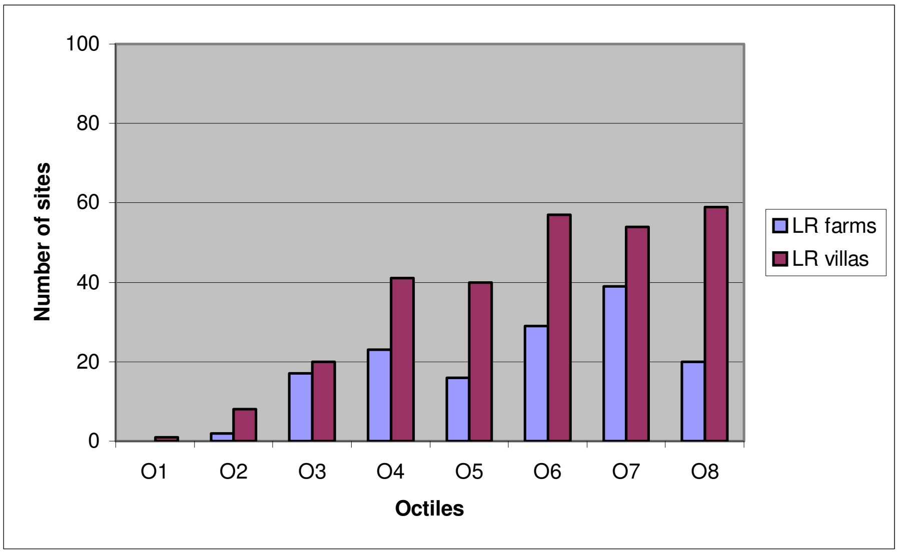


Figure 5.8 Bar chart showing number of sites in each octile range (Late Republican model 1a)

Comparing the Late Republican sites to the quartile divisions showed that the number of villas of this period increased with more suitable classes (Table 5.6 and Figure 5.7). Late Republican farms followed this pattern in general but had fewer numbers, therefore the increase was less dramatic. The octile divisions show a more variable pattern (Table 5.7 and Figure 5.8). Though there is still a general increase in villas this is not as linear as the previous analysis, with three distinct peaks (O_4, O_6 and O_8). Farms are more variable still, with a bimodal distribution, peaking at O_4 and O_7. The Early Imperial sites were next tested in order to see if the patterns demonstrated here were emphasised with a larger sample of sites

A new multi-criteria analysis was therefore carried out using the same factors and constraints, but with Early Imperial urban centres as a factor map instead of the Late Republican centres. The expected outcome was that, overall, there would be more suitable land, given that the urban centres were more numerous in this later period. However, as can be seen from the graph (Figure 5.9), the differences were minimal in the suitability of land, with quartile divisions remaining the same. Dividing the land suitability into octiles showed very slight differences from the Late Republican distribution. Again, however, the most obvious pattern was that there is very little of the least suitable land in the study area (O_1).

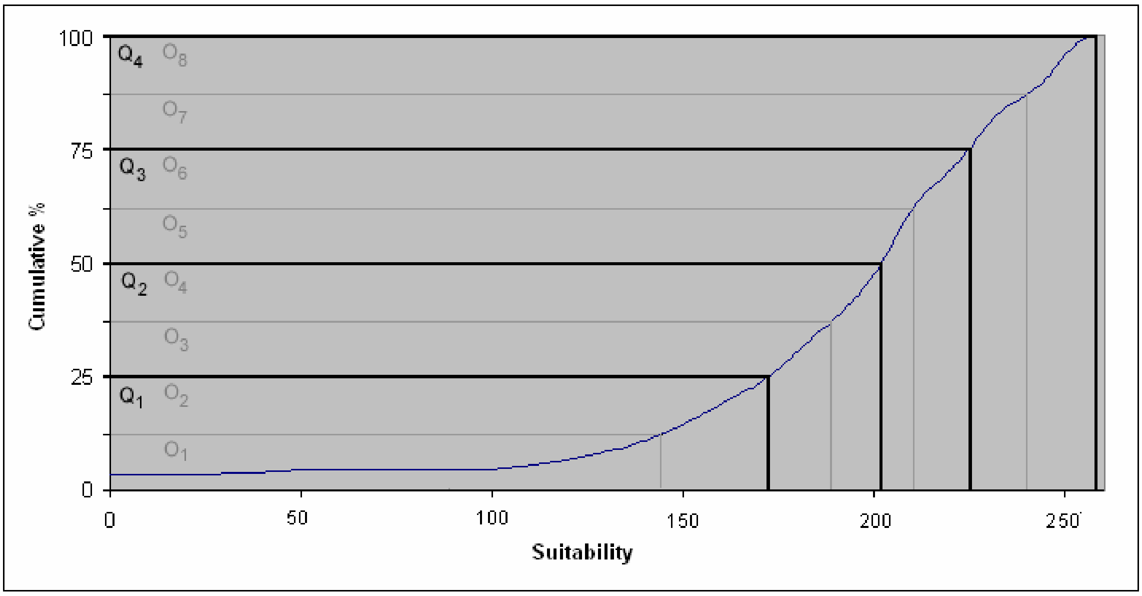


Figure 5.9 Graph showing quartiles and octiles of suitability distribution (Early Imperial model 1b)

Table 5.8 Number of Early Imperial sites in each suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	EI farms	EI villas	% EI farms	% EI villas
Q_1	0-169	169	9	18	1.68	2.76
Q_2	170-199	29	126	133	23.55	20.37
Q_3	200-221	21	166	234	31.03	35.83
Q_4	222-255	33	234	268	43.74	41.04

Table 5.9 Number of Early Imperial sites in each suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	EI farms	EI villas	% EI farms	% EI villas
O_1	0-141	141	0	5	0.00	0.77
O_2	142-168	26	9	13	1.68	1.99
O_3	169-185	16	42	50	7.85	7.66
O_4	186-198	12	84	83	15.70	12.71
O_5	199-207	8	69	107	12.90	16.39
O_6	208-221	13	97	127	18.13	19.45
O_7	222-237	15	131	149	24.49	22.82
O_8	238-255	17	103	119	19.25	18.22

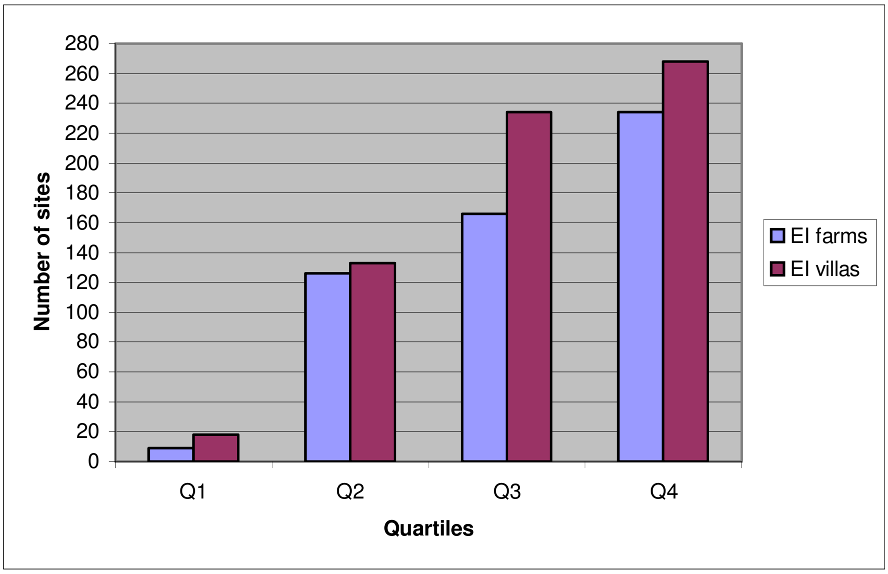


Figure 5.10 Bar chart showing number of sites in each quartile range (Early Imperial model 1b)

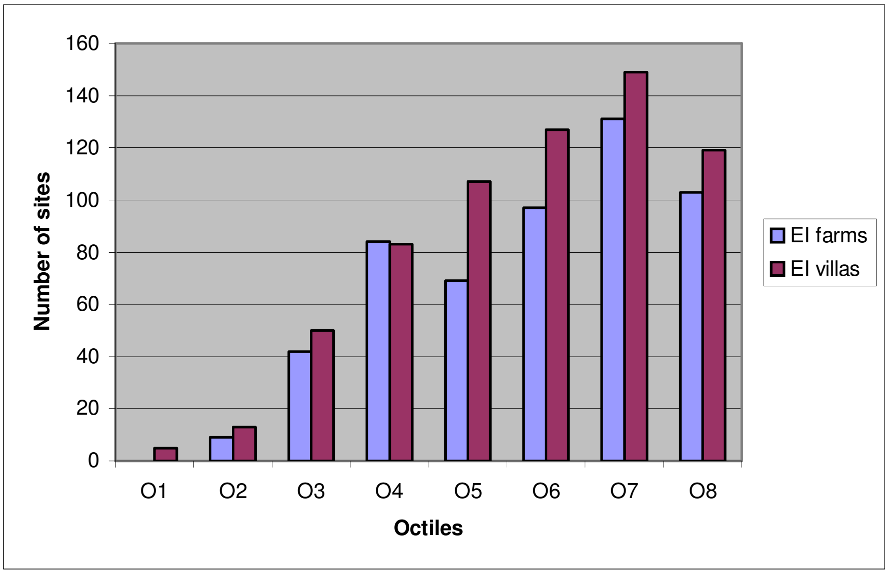


Figure 5.11 Bar chart showing number of sites in each octile range (Early Imperial model 1b)

Comparing the distribution of Early Imperial sites showed that the majority occurred in Q_4 – the areas with the highest suitability for wheat cultivation (Table 5.8 and Figure 5.10). As expected, there is a more pronounced pattern than can be seen than with the Late Republican sites due to the higher sample size. For villas the top two quartile ranges contain similar numbers of sites, whilst the farms show a more linear distribution. The octile divisions, however, do not demonstrate the expected pattern (Table 5.9 and Figure 5.11). The villa distribution has only one peak, in O_7, showing a gradual increase in site number compared to suitability, with a slight drop-off in the very highest category. Farms, on the other hand, are still showing a bimodal distribution with peaks in O_4 and O_7, though more pronounced than the Late Republican results.

It is clear from both the Late Republican and Early Imperial results that there is increasing usage of the suitable land (visible with both quartile and octile divisions) and, despite the bimodal distribution, the top 3 octile ranges ($O_{6\text{-}8}$) contained the highest number of villas and farms in both periods. The two lowest octile ranges seem to have been generally avoided. With the higher density of sites in the Early Imperial period we see the same preference for more suitable areas, but the number of sites on less suitable areas is slightly increased. This could be interpreted as related to population pressures forcing farmers to work more marginal lands or that these other lands were suitable for alternative economies such as olive or vine growing, or pastoral activities.

5.3.2 MCE for wheat cultivation: Evaluation Two

The second wheat evaluation used weighted linear combination using the same factors as Evaluation 1. Each factor was weighted according to their importance. As stated previously (Section 5.2.1) an element of conjecture was applied, and Roman farmers were assumed to have prioritised ease of cultivation above social factors such as proximity to transport or markets (Figure 5.12).

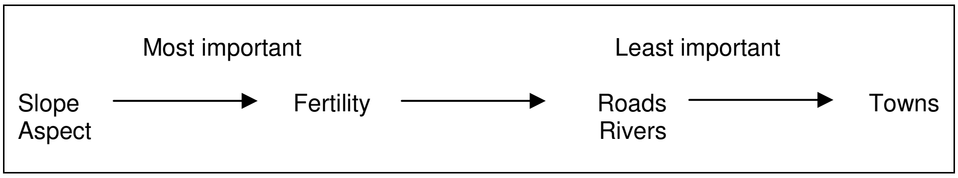


Figure 5.12 Order of importance for factors

In the pairwise comparison matrix (Table 5.10), slope and aspect were deemed to be the most important factors, with an equal weighting (Table 5.11 shows the derived weights). Productivity was the next most important factor. The position of productivity as only second-most important may be considered odd given the probable desire for high returns, but it has been argued that the Romans saw ease of work rather than fertility as the most important factor in crop production (Verhagen 2002: 202). Measures could be taken to improve soil fertility and farmers did not always farm the best soil only, but little could be done to improve the ease of farming on steep slopes. Distance to rivers and roads were considered for this analysis to be less important still, again with an equal weighting. The least important factor was proximity to towns, as it was assumed in this instance that proximity to transport routes took precedence over direct urban accessibility.

> *A farm is rendered more profitable by convenience of transportation: if there are roads on which carts can be easily driven, or navigable rivers near by. We know that transportation to and from many farms is carried on by both these methods.*
>
> Varro *Rust.* 1.16.6

Table 5.10 Pairwise comparison matrix for Evaluation #2

	Slope	Aspect	Productivity	Dist water	Dist roads	Dist towns
Slope	1					
Aspect	1	1				
Productivity	1/3	1/3	1			
Dist water	1/5	1/5	1/3	1		
Dist roads	1/5	1/5	1/3	1	1	
Dist towns	1/7	1/7	1/5	1/3	1/3	1

Table 5.11 Weightings for weighted linear combination using figures from Table 5.10

Slope	0.3358
Aspect	0.3358
Productivity	0.1564
Distance to rivers	0.0691
Distance to roads	0.0691
Distance to towns	0.0336
Sum of all eigenvectors	1
Consistency ratio	0.03

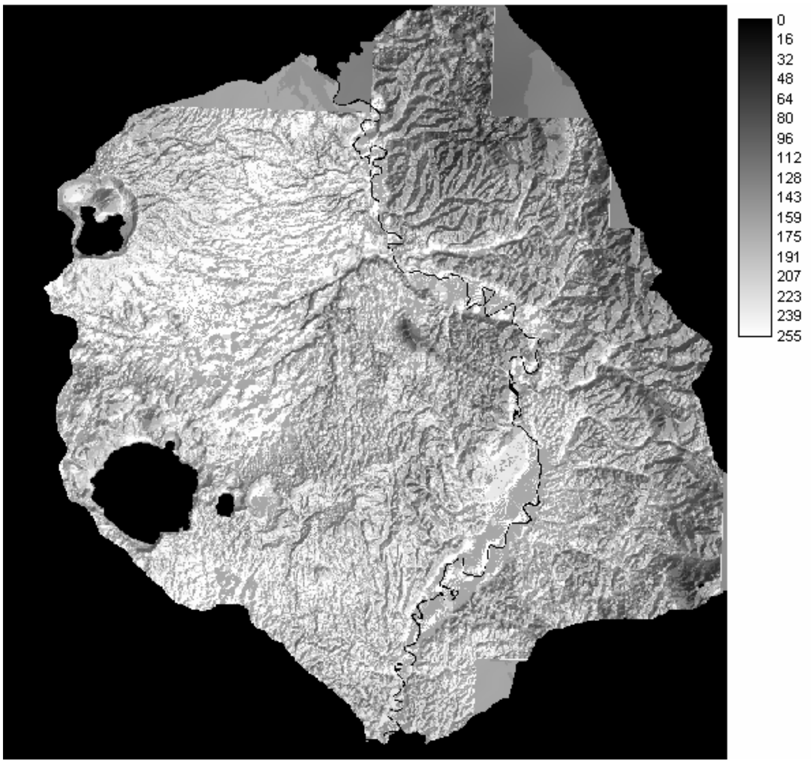


Figure 5.13 Suitability map for wheat created using weighted multi-criteria evaluation (Late Republican model 2a)

The graph (Figure 5.14) shows the distribution of suitable land to be quite different from the previous model. The most dominant land suitability is Q_2, and the most suitable land category (Q_4) covers a fairly large range, thereby indicating that there is less of the very suitable land in this model. Dividing into octiles demonstrates more variability. O_4 represents the most dominant suitability value, with a very small inter-octile range of only 4, though in this example the very highest suitability (O_8) was almost as common, with a range of 5 (Table 5.13), a fact that is disguised with the quartile divisions.

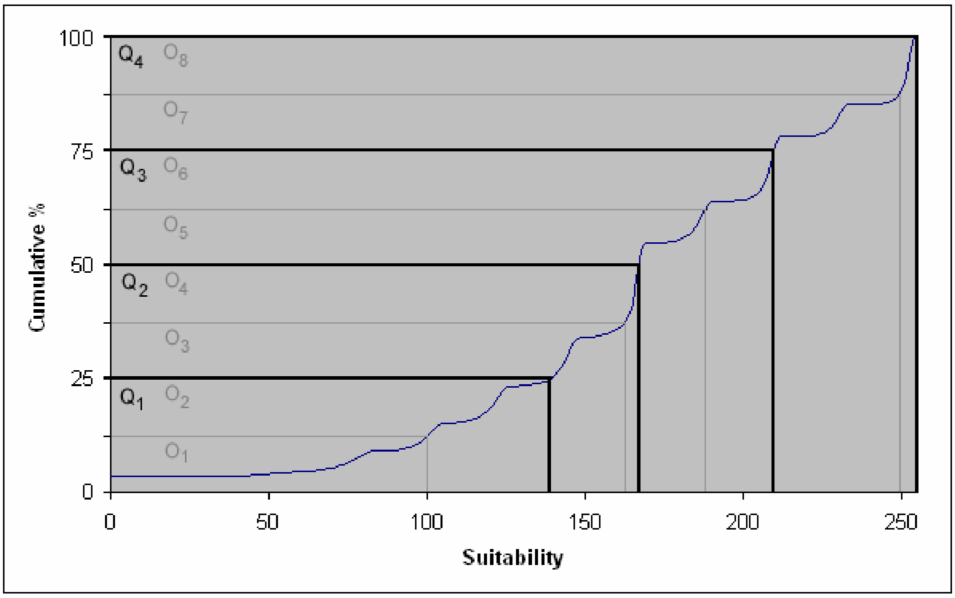


Figure 5.14 Graph showing quartiles and octiles of suitability distribution (Late Republican model 2a)

Table 5.12 Number of Late Republican sites in each suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	LR farms	LR villas	% LR farms	% LR villas
Q_1	0-139	139	9	17	6.16	6.07
Q_2	140-167	27	40	72	27.40	25.71
Q_3	168-209	41	39	78	26.71	27.86
Q_4	210-255	45	58	113	39.73	40.36

Table 5.13 Number of Late Republican sites in each suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	LR farms	LR villas	% LR farms	% LR villas
O_1	0-100	100	1	2	0.68	0.71
O_2	101-139	38	8	15	5.48	5.36
O_3	140-162	22	17	29	11.64	10.36
O_4	163-167	4	23	43	15.75	15.36
O_5	168-188	20	14	32	9.59	11.43
O_6	189-209	20	25	46	17.12	16.43
O_7	210-249	39	34	54	23.29	19.29
O_8	250-255	5	24	59	16.44	21.07

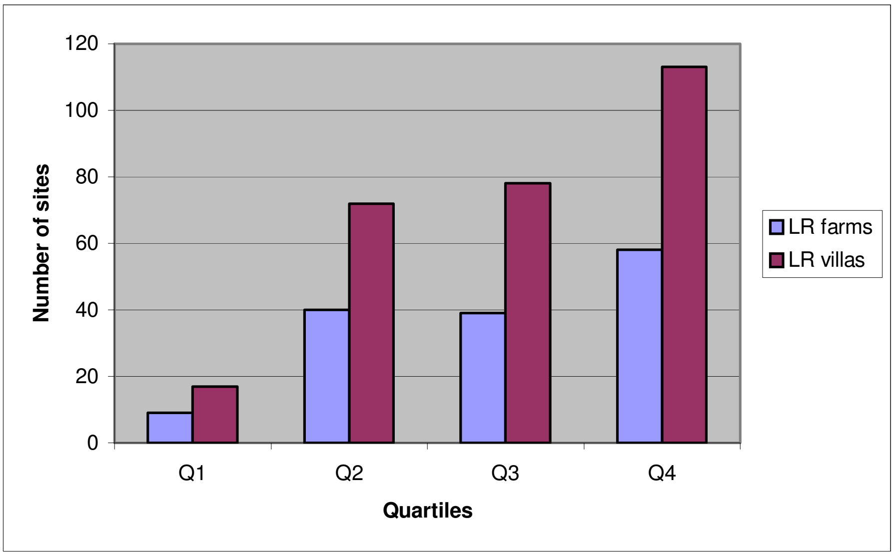


Figure 5.15 Bar chart showing number of sites in each quartile range category (Late Republican model 2a)

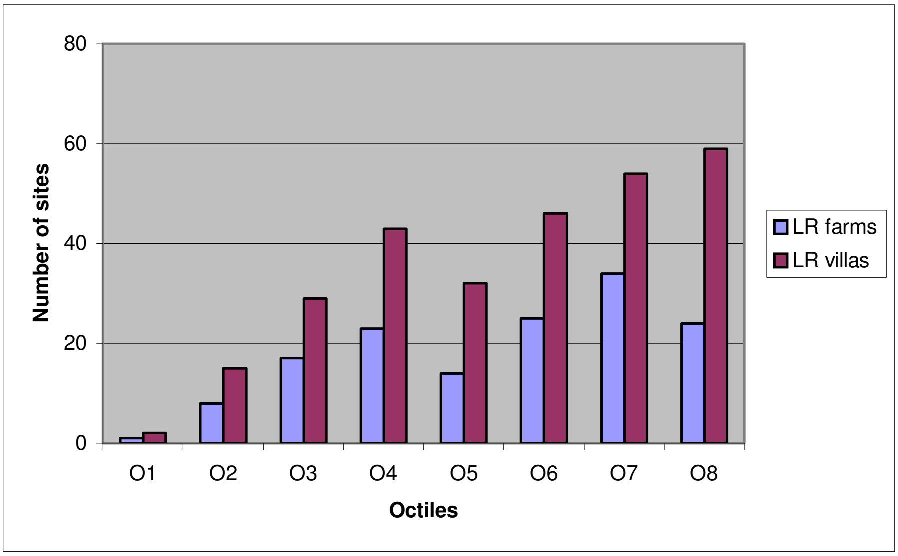


Figure 5.16 Bar chart showing number of sites in each octile range category (Late Republican model 2a)

Looking at the distribution of sites against these divisions (Table 5.12 and Figure 5.15), there is again a definite trend towards the land more suitable for wheat production, with increasing numbers of villas in each quartile range. Farms show a very slight bimodal distribution as Q_2 contains more farms than Q_3. In the octile divisions (Table 5.13 and Figure 5.16), sites are distributed more unevenly than is suggested by the quartile analysis. Though the top two octiles contain the highest number of villa sites, there is also a peak in O_4. Again, this may relate to sites being situated to take advantage of other resources or different crops. Farms peak in O_7 and again in O_4, following a similar pattern to the villas, though not utilising the most suitable land.

The Early Imperial data shows a similar trend, with the land suitability following the same overall curve (Figure 5.17). The site distributions, however, show a different pattern. With the quartile divisions, both the villas and farms show an almost exponential increase in the use of the higher suitability land (Table 5.14 and Figure 5.18). The octile divisions, however show a multimodal distribution of both farms and villas. (Table 5.15, and Figure 5.19). Villas peak at O_3, O_5 and O_8, whilst farms peak at O_3, O_5 and O_7 (though there is only one more farm on O_7 than on O_8). Overall, however, the top two octile ranges contain by far the largest number of farms and villas.

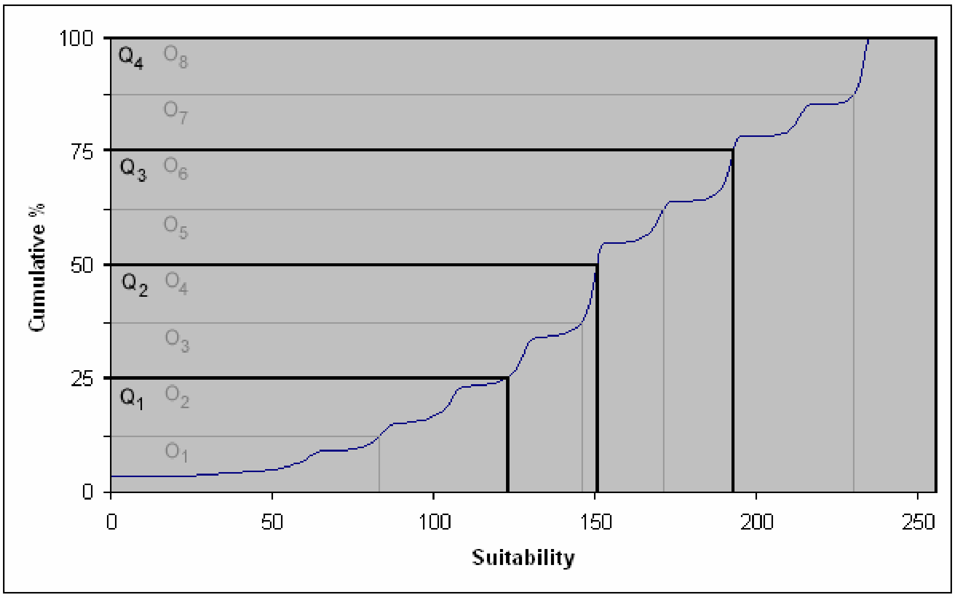


Figure 5.17 Graph showing quartiles and octiles of suitability distribution (Early Imperial model 2b)

Table 5.14 Number of Early Imperial sites in each suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	EI farms	EI villas	% EI farms	% EI villas
Q_1	0-122	122	23	24	4.30	3.68
Q_2	123-150	27	43	74	8.04	11.33
Q_3	151-192	41	162	205	30.28	31.39
Q_4	193-255	62	307	350	57.38	53.60

Table 5.15 Number of Early Imperial sites in each suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	EI farms	EI villas	% EI farms	% EI villas
O_1	0-83	83	0	5	0.00	0.77
O_2	84-122	38	23	19	4.30	2.91
O_3	123-145	22	33	55	6.17	8.42
O_4	146-150	4	10	19	1.87	2.91
O_5	151-171	20	121	141	22.62	21.59
O_6	172-192	20	41	64	7.66	9.80
O_7	193-230	37	154	171	28.79	26.19
O_8	231-255	24	153	179	28.60	27.41

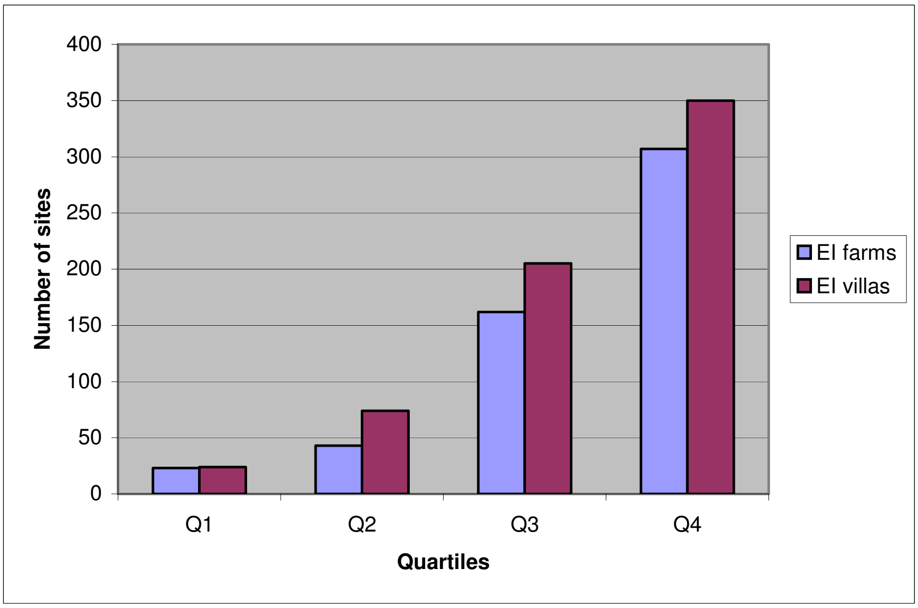


Figure 5.18 Bar charts showing number of sites in each quartile range (Early Imperial model 2b)

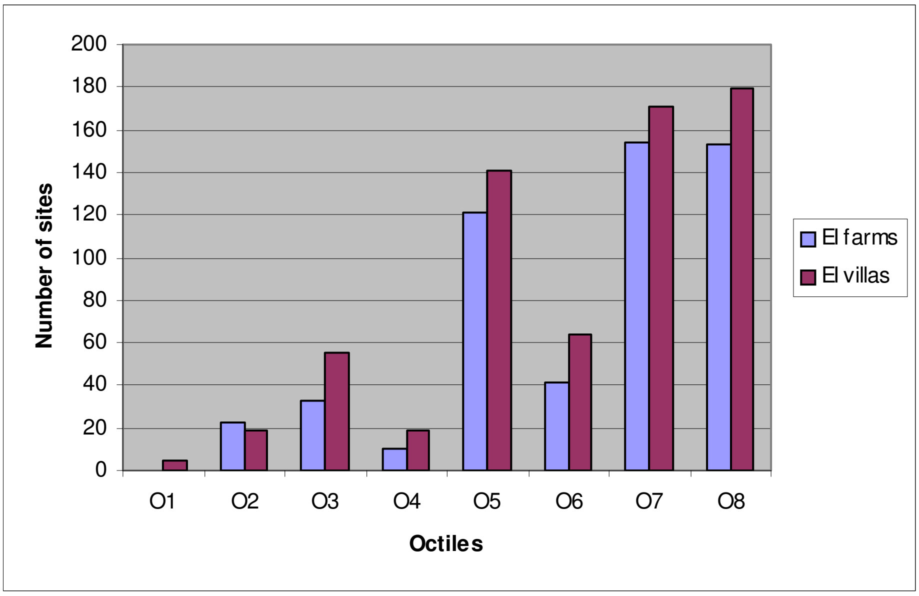


Figure 5.19 Bar charts showing number of sites in each octile range (Early Imperial model 2b)

Broadly the two main evaluations for wheat suitability (Sections 5.3.1 and 5.3.2) show similar trends, as the majority of Roman rural sites were located on the more suitable categories for arable agriculture. As stated above, these results may partly reflect biases in the sample of sites used but, irrespective of known site location, the models do show that large areas of the study area – particularly in South Etruria – are considered suitable for wheat cultivation according to the recommendations of the agronomists, and highlight areas within the surveyed regions which may be considered less suitable for such field crops. The model showing a lower peak in suitability may be interpreted as sites located to take advantage of other resources. In order to give a more rounded picture of the ancient economy, consequently, more models were run using other agricultural and pastoral activities.

5.4 Criteria used for modelling olive suitability

The olive is a much more difficult crop to quantify than field crops such as wheat. The evidence is far scarcer and often contradictory. For example, Columella (*Rust.* 5.8.1) praises the olive as being a crop that is easily cultivated and capable of producing a high yield, calling it the "*queen of trees*". On the contrary, the Elder Pliny (*NH* 18.38) states that "*olives are not easily made to pay*". The Sabine hills were nevertheless known from antiquity as being famous for oleoculture (Varro *Rust*. 1.2.7, Pliny *NH* 15.8; Columella *Rust.* 5.8.5). This is still the case today, as can be seen from the modern land use map (Figure 5.20, page 220), with a large percentage of olive cultivation occurring in this area. Looking at the suitability maps created above for cereals (Figures 5.5 and 5.13) we can see why this area, as opposed to South Etruria, may have been regarded as conducive to this type of economy.

The area of the Sabina is generally hillier with thinner soils. The growing of olives is not difficult in hilly areas, and can actually help to prevent the erosion of hillsides. In this type of area, wheat may also be grown between the rows of trees. This would mean that choosing this type of economic strategy (intercropping of wheat and olives, see Section 5.6) would maximise the productive potential of what is essentially a poor area in terms of general fertility. However, an altitude of approximately 500-700 metres above sea level is the upper limit for successful cultivation (Marcaccini 1973: 31-49; in Mattingly 1996: 215), meaning that the more mountainous areas towards the Apennines are merely suitable for economic strategies such as pastoralism or forest. This is also reflected in Columella (*Rust.* 5.8.5) where he describes the olive as not liking,

> *…either low lying or lofty situations but prefers moderate slopes such as we see in the Sabine territory in Italy.*

For this suitability classification, the main differences between this and the previous model for wheat are slope factor, aspect, and soil fertility. The other social factors of distance to rivers, roads and towns remained the same. The slope factor classification (Table 5.16) was altered to reflect that olives prefer to grow on slopes and can grow in steeper areas. Very flat areas were avoided in this classification as they do not drain as well as slight slopes, and therefore are prone to waterlogging which is detrimental to olive trees.

> [A farm] *that is perfectly level … having no outlet for the water, tends to become marshy*
>
> Varro *Rust.* 1.6.6

> *Chalk must be wholly rejected, and even more land which abounds in springs and where ooze is always standing.*
>
> Columella *Rust.* 5.8.6-7

Table 5.16 Reclassification for gentle to moderate slopes (after Soil Survey Division Staff 1993: chap. 3, tab. 3.1)

Slope type	Percent slope	Classification
Nearly level	0-2	1
Gently sloping / undulating	2-8	255
Strongly sloping / rolling	8-13	255
Moderately steep / hilly	13-25	255
Steep	25-55	127
Very steep	55+	1

For aspect, Cato (*de Agr.* 6.2) stated that,

> *…land which is suitable for olive planting is that which faces the west and is exposed to the sun.*

This differs from the predominantly south-east-facing arable. Looking at the location of modern olives (Table 5.17) it is clear that a number of different aspects are considered suitable nowadays, as they are well distributed between different aspects. However, as west-facing slopes were considered appropriate by Columella this was used for creating the factor map (Table 5.18). The western aspect, as well as north-west and south-west, was given the highest rating, whilst the remaining aspects (with the exception of flat which was unsuitable) were given a medium classification.

Table 5.17 Location of modern olives in relation to aspect

	% of modern olives
North	8.24
North-East	9.08
East	10.20
South-East	13.92
South	15.90
South-West	16.96
West	14.32
North-West	10.01
Flat	1.37

Table 5.18 Reclassification of aspect to reflect the agronomists' recommendations for olives

	Classification
North	127
North-East	1
East	1
South-East	1
South	127
South-West	255
West	255
North-West	255
Flat	1

For fertility, again we looked to the geology. According to Columella (*Rust*. 5.8.6-7):

> *The most suitable ground for olives is that which has gravel underneath, if chalk mixed with coarse sand forms the top-soil. Not less highly esteemed is ground where there is rich sand, but denser soil is also well adapted to this tree, if it is moist and fertile. Chalk must be wholly rejected, and even more land which abounds in springs and where ooze is always standing. Land which is lean because of sand is unfriendly to the olive-tree; so is bare gravel: for, although it does not die in this kind of soil, yet it never acquires strength.*

Cato and Varro are less explicit. Cato (*de Agr*. 6.1-2; 40.2) merely states that heavy, warm soil is suited to oleoculture, whilst the Licinian olive variety specifically needs a colder, thinner soil. This is then quoted by Varro (*Rust*. 1.24.1-2) who adds nothing to this description. Virgil, however, is quite descriptive regarding suitable soils for olives.

> *First a stubborn soil and inhospitable hills,*
> *Where the clay is lean and the fields are strewn with stones and brushwood.*
> *Delight in the long-lived olive*
>
> Virgil *Georg*. 2.179-181

Varro (*Rust*.1.24.2) also states, in regard to the Licinian olive particularly, that,

> *…if you plant it in rich or warm soil the yield will be worthless.*

Pliny the Elder (*NH* 17.223) also states that olive trees are more prone to disease when planted in rich soils, and the oil is inferior that that produced on poorer, rockier ground. Pliny states that, in Italy (particularly Venafrum), a gravelly soil is best suited to oleoculture (*NH* 17.31). However, in this passage he does highlight the variability in suitable soils in different areas. He is also the only author to mention the importance of lime (although chalk has been mentioned above by Columella).

> *The Ædui and the Pictones have rendered their lands remarkably fertile by the aid of limestone, which is also found to be particularly beneficial to the olive and the vine.*
>
> Pliny *NH* 17.47

> *In more recent times it has been found that the olive thrives more particularly in soil that has been manured with the ashes of the lime-kiln.*
>
> Pliny *NH* 17.53-54

Pliny (*NH* 17.128-129) also draws attention to the work of Mago (now lost), who states that olives should be grown in dry spots in argillaceous (clayey) soil, although he does point out that this applies to Africa specifically.

Although these descriptions are variable, certain passages are highly comparable to the modern situation. The general impression given by all these sources is that, though there is some difference in requirements between particular varieties, olives in general can prosper on poorer, drier soils than other crops, particularly gravelly, sandy soils, with some limestone/chalk (Table 5.19).

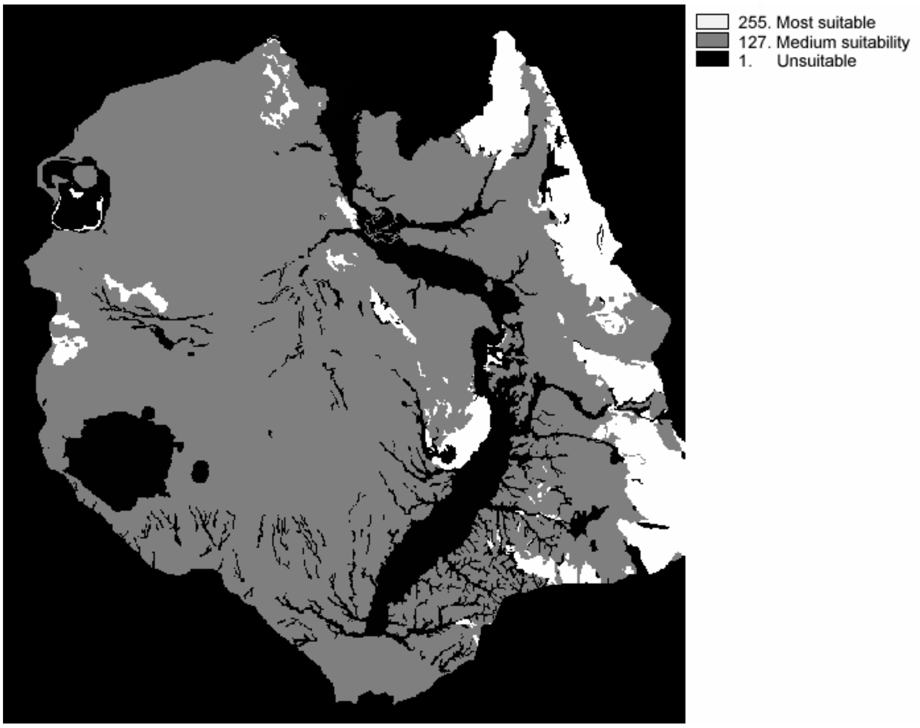
Table 5.19 Suitability of soils for oleoculture according to the agronomists

	Suitable	Marginally suitable	Unsuitable
Columella	Gravel subsoil and mixed chalk/sand topsoil	Bare gravel	Chalk
	Rich sand	Thin unproductive sands	Land with springs, marshy ground, etc.
	Moist, fertile dense soil		
Cato and Varro	Heavy, warm soil		Rich or warm soil (Licinian)
	Colder, thinner soil (Licinian)		
Pliny	Gravelly soil	Rich soils	
	Limestone		
Mago	Clayey soils (Africa)		

In order to create a factor map to show suitability for olive cultivation, calcareous geology types were given a high suitability, as well as types likely to create gravelly or sandy soils. Non-calcareous soils were given a medium classification as well as those soils likely to be rich (i.e. the volcanic deposits). If the soil produced by the geology type was likely to be too rocky or not well drained/marshy, this was given a low classification (see Appendix IV, Table IV.2 for classifications).

The resulting factor map shows, perhaps unsurprisingly, that many areas that were almost totally unsuitable for arable cultivation are actually very good for oleoculture, most notably the limestone outcrops of the pre-Apennines (Figure 5.20a). However, most of South Etruria shows a medium suitability for olive cultivation, which means that either arable or olives could be grown in this region. Comparison with the modern land use map (Figure 5.20b) also shows a great deal of overlap in areas cultivated in this way.

a.



b.

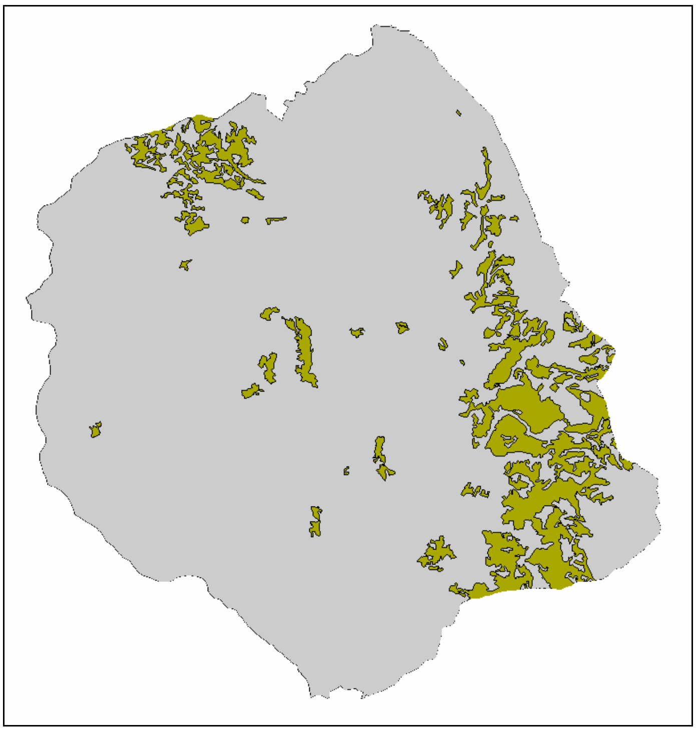


Figure 5.20 a) Potential fertility map for olives and b) location of modern olives from the land use map (British School at Rome)

5.4.1 MCE for olive cultivation: Evaluation Three

For the first olive evaluation the factors used were slope, aspect, fertility, and cost distance to rivers, roads and urban centres. The analysis used equal weighting within the multi-criteria evaluation, and used altitude (i.e. nothing over 700m) and lakes as constraints. The expected result was that a larger area would be suitable for olive cultivation than for cereals. This map could then be compared to the cereal suitability in order to identify areas *only* suitable for olives and not cereals, and *vice versa*.

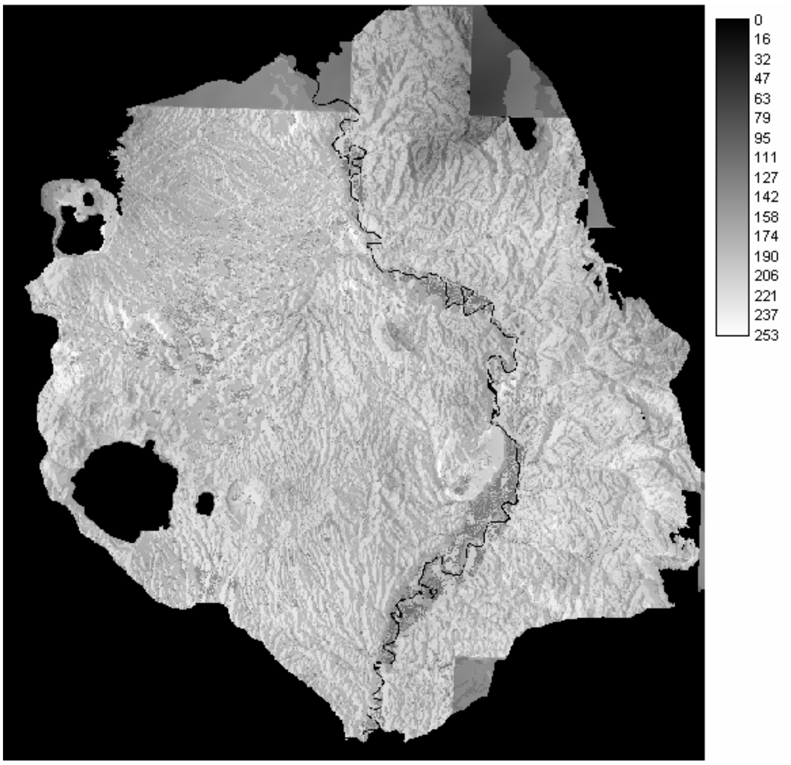


Figure 5.21 Suitability map for olives created using weighted multi-criteria evaluation (Late Republican model 3a)

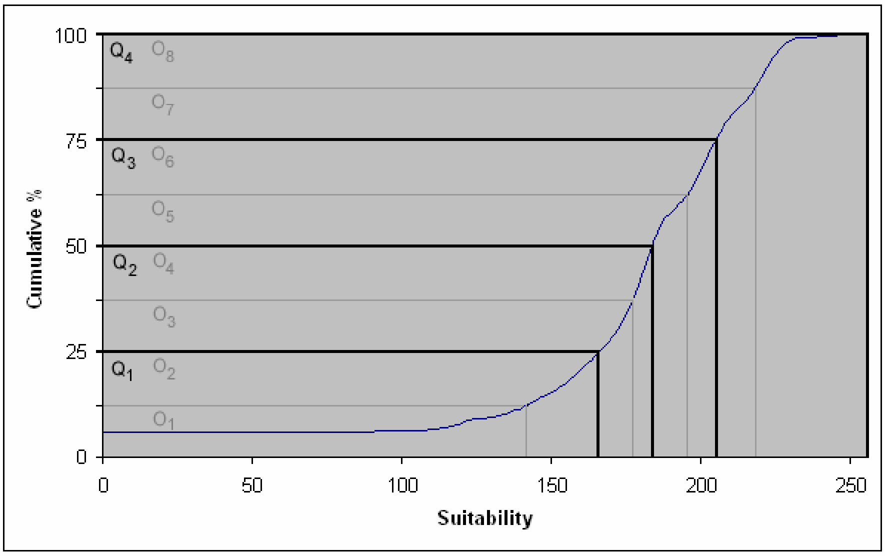


Figure 5.22 Graph showing quartiles and octiles of olive suitability distribution (Late Republican model 3a)

This graph (Figure 5.22) confirms that there are, as hypothesised, large areas suitable for olive cultivation. This is demonstrated by the very large lower quartile, which shows that the lowest 25% of the area includes over half of the suitability values. Most land was of average suitability in the middle two quartiles.

Table 5.20 Number of Late Republican sites in each suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	LR farms	LR villas	% LR farms	% LR villas
Q_1	0-165	165	9	20	6.16	7.14
Q_2	166-183	17	42	84	28.77	30.00
Q_3	184-204	20	34	73	23.29	26.07
Q_4	205-255	50	61	103	41.78	36.79

Table 5.21 Number of Late Republican sites in each suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	LR farms	LR villas	% LR farms	% LR villas
O_1	0-141	141	2	6	1.37	2.14
O_2	142-165	23	7	14	4.79	5.00
O_3	166-177	11	32	42	21.92	15.00
O_4	178-183	5	10	42	6.85	15.00
O_5	184-195	11	21	35	14.38	12.50
O_6	196-204	8	13	38	8.90	13.57
O_7	205-217	12	32	36	21.92	12.86
O_8	218-255	37	29	67	19.86	23.93

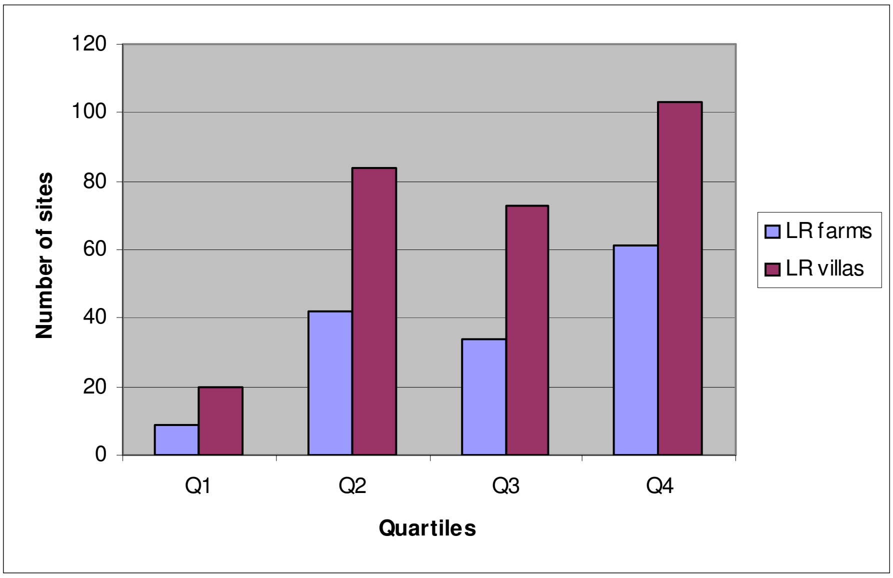


Figure 5.23 Bar chart showing number of sites in each quartile range (Late Republican model 3a)

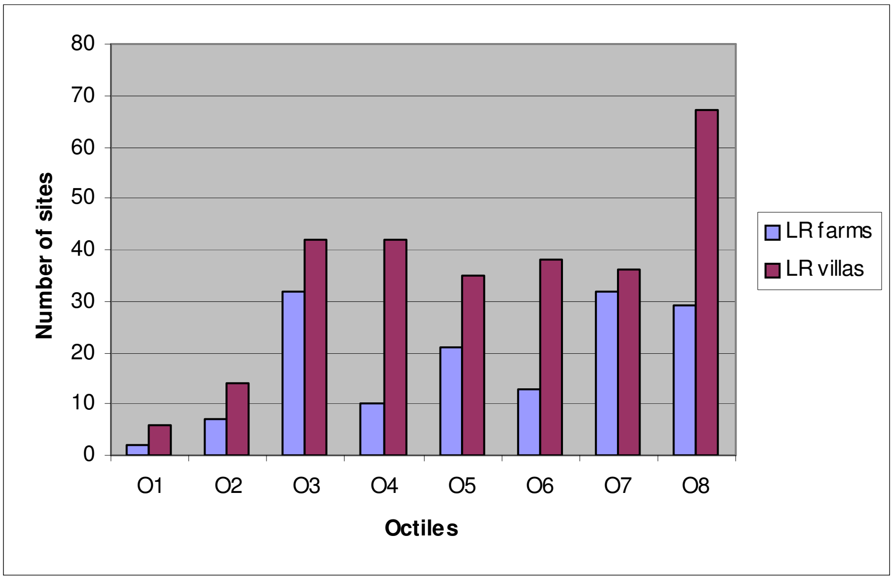


Figure 5.24 Bar chart showing number of sites in each octile range (Late Republican model 3a)

The results when comparing the Late Republican site to the quartile divisions show less of an obvious pattern than the wheat evaluations (Table 5.20 and Figure 5.23). Although generally less suitable land is avoided and the most suitable quartile contains the highest number of sites, there is more variability in the remaining classes. Dividing further into octiles shows this more clearly (Table 5.21 and Figure 5.24). Villas seem to be significantly more numerous in O_8, whilst distribution is fairly even between O_{3-7} than the previous evaluations. This difference is more pronounced in the results for farms, with the highest number of sites on O_3 and O_7 and a great deal of variability between octiles.

The Early Imperial results again show similar trends, with the distribution of suitability almost exactly the same (Figure 5.25). The larger sample of sites also follows similar trends than the Late Republican sample (Tables 5.22 and 5.23). Figure 5.26 shows that the farms are following similar patterns to the villas when divided into quartiles. This differs from the Late Republican analysis as the farms showed more variability previously. Dividing into octiles (Figure 5.27) demonstrates this more clearly as, again, the farms are following the same exploitation pattern as the villas, with peaks in O_4 and O_8.

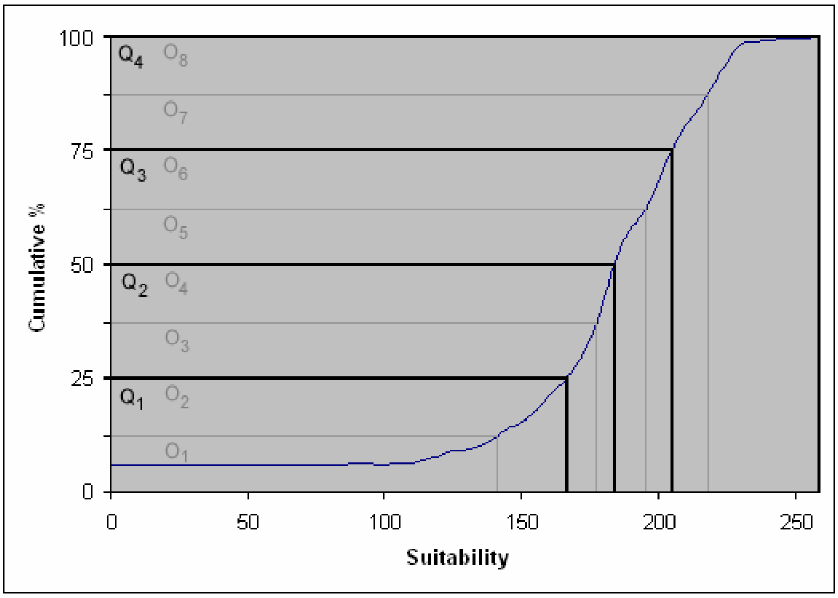


Figure 5.25 Graph showing quartiles and octiles of olive suitability distribution (Early Imperial model 3b)

Table 5.22 Number of Early Imperial sites in each suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	EI farms	EI villas	% EI farms	% EI villas
Q_1	0-165	165	32	48	21.92	17.14
Q_2	166-183	17	191	195	130.82	69.64
Q_3	184-204	20	142	172	97.26	61.43
Q_4	205-255	50	170	238	116.44	85.00

Table 5.23 Number of Early Imperial sites in each suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	EI farms	EI villas	% EI farms	% EI villas
O_1	0-141	141	13	15	8.90	5.36
O_2	142-165	23	19	33	13.01	11.79
O_3	166-176	10	79	68	54.11	24.29
O_4	177-183	6	98	114	67.12	40.71
O_5	184-194	10	50	73	34.25	26.07
O_6	195-204	9	82	93	56.16	33.21
O_7	205-217	12	69	86	47.26	30.71
O_8	218-255	37	101	152	69.18	54.29

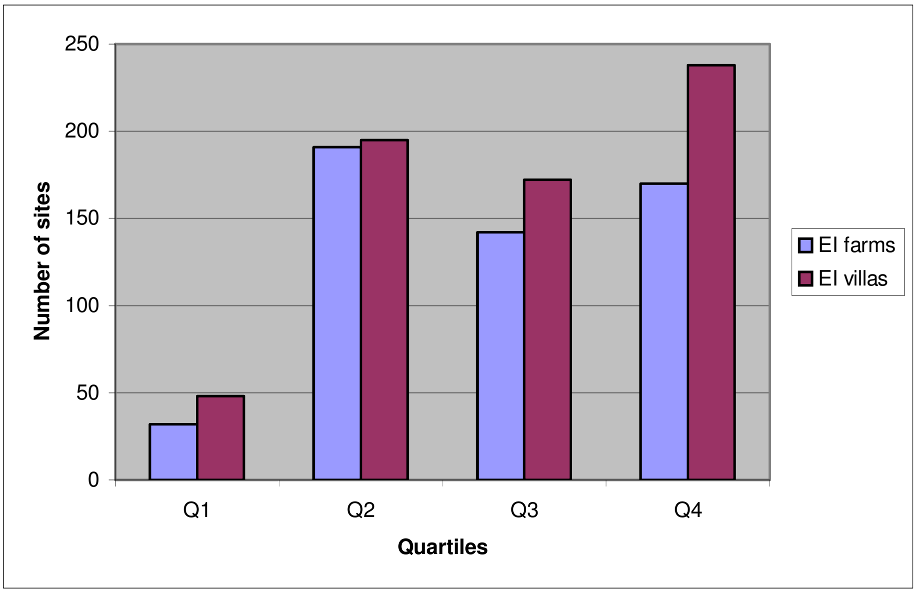


Figure 5.26 Bar chart showing number of sites in each quartile range (Early Imperial model 3b)

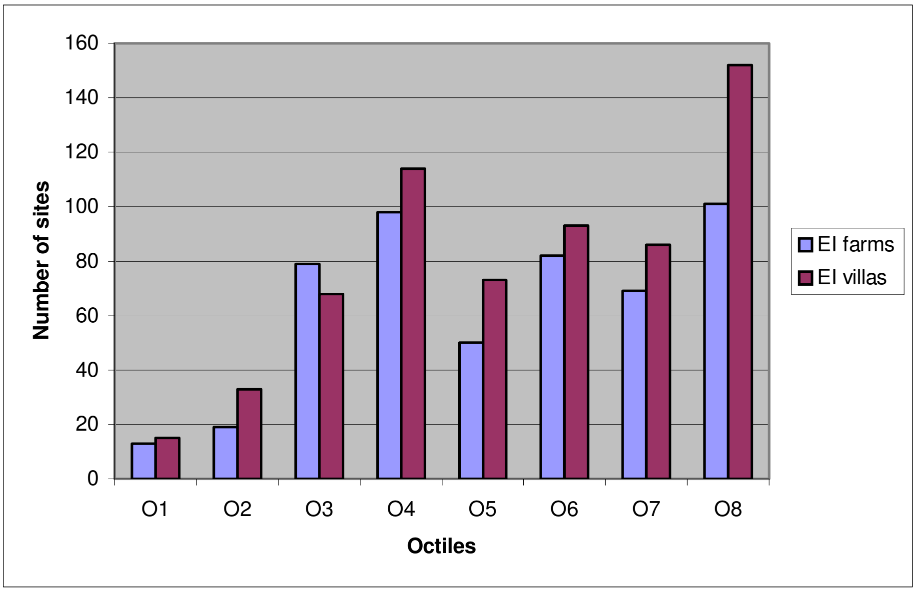


Figure 5.27 Bar chart showing number of sites in each octile range (Early Imperial model 3b)

5.4.2 MCE for olive cultivation: Evaluation Four

The next model (Figure 5.28) used the same weighted linear combination as arable model #2 (Section 5.3.2).

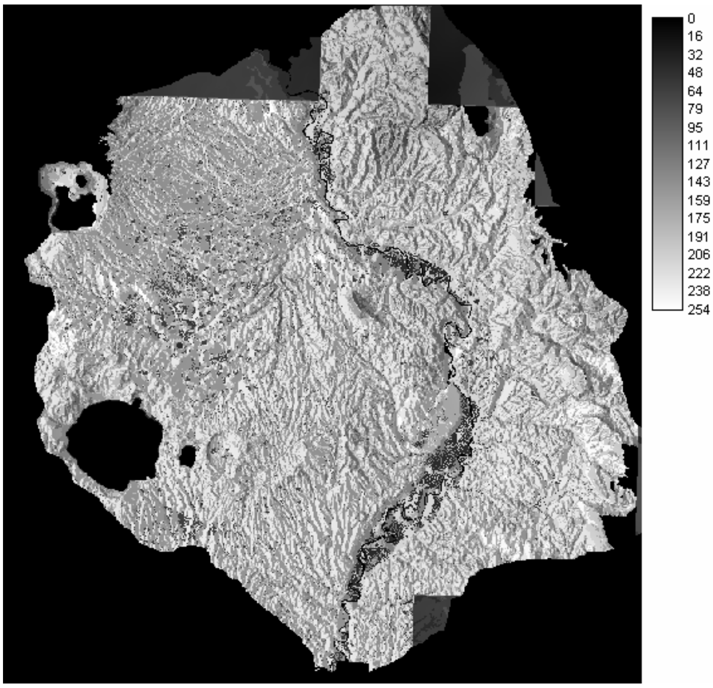


Figure 5.28 Suitability map for olives created using weighted multi-criteria evaluation (Late Republican model 4a)

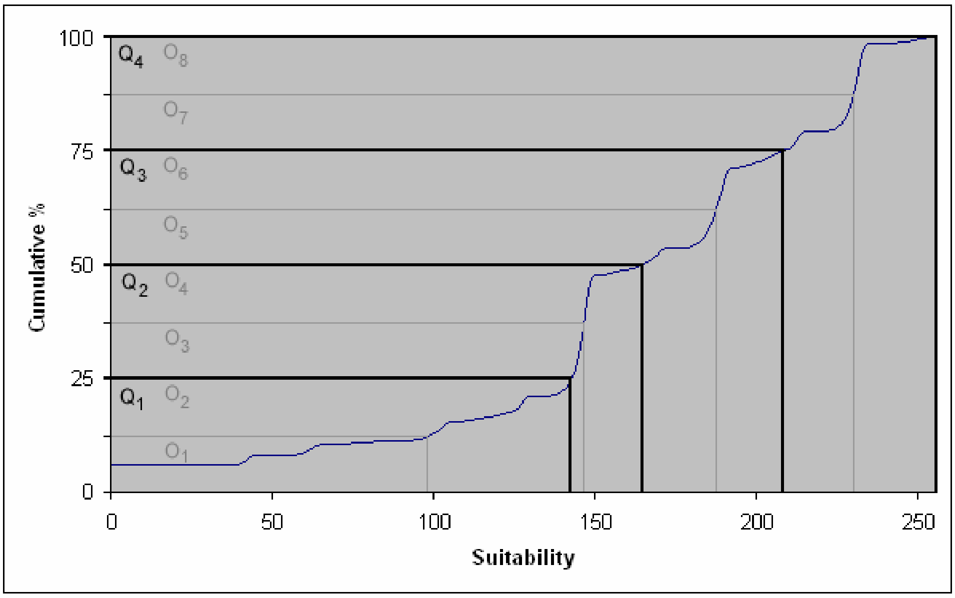


Figure 5.29 Graph showing quartiles and octiles of olive suitability distribution (Late Republican model 4a)

Quartiles were quite different in their distribution to the previous evaluation. The lower suitability of land was more frequent than all the previous models as shown in Figure 5.29. There also appeared to be a threshold in the distribution of land, which increased suddenly in Q_2. This is more evident in the octile divisions, where O_3 is by far the most dominant land suitability (Table 5.25).

Table 5.24 Number of Late Republican sites in each olive suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	LR farms	LR villas	% LR farms	% LR villas
Q_1	0-142	142	12	23	8.22	8.21
Q_2	143-164	21	48	96	32.88	34.29
Q_3	165-208	43	34	67	23.29	23.93
Q_4	209-255	46	52	94	35.62	33.57

Table 5.25 Number of Late Republican sites in each olive suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	LR farms	LR villas	% LR farms	% LR villas
O_1	0-98	98	4	8	2.74	2.86
O_2	99-142	43	8	15	5.48	5.36
O_3	143-146	3	33	52	22.60	18.57
O_4	147-164	17	15	44	10.27	15.71
O_5	165-187	22	15	24	10.27	8.57
O_6	188-208	20	19	43	13.01	15.36
O_7	209-230	21	26	28	17.81	10.00
O_8	231-255	24	26	66	17.81	23.57

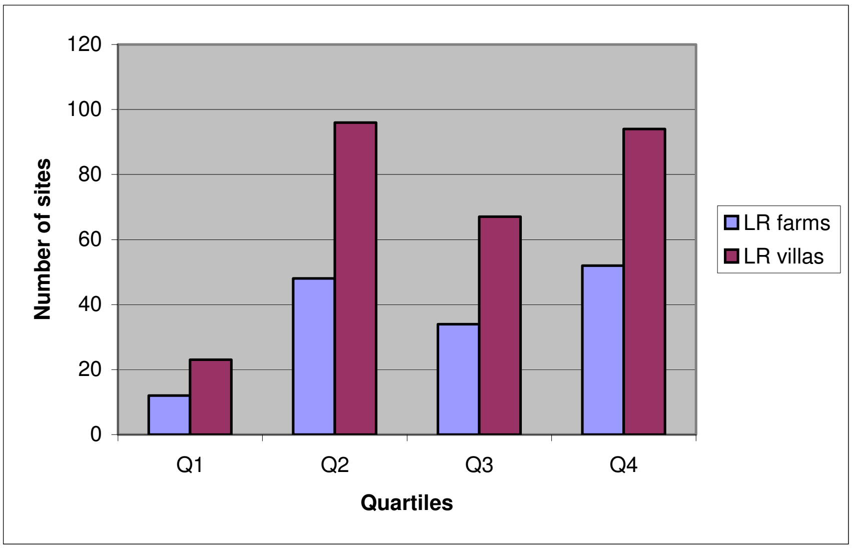


Figure 5.30 Bar chart showing number of sites in each quartile range (Late Republican model 4a)

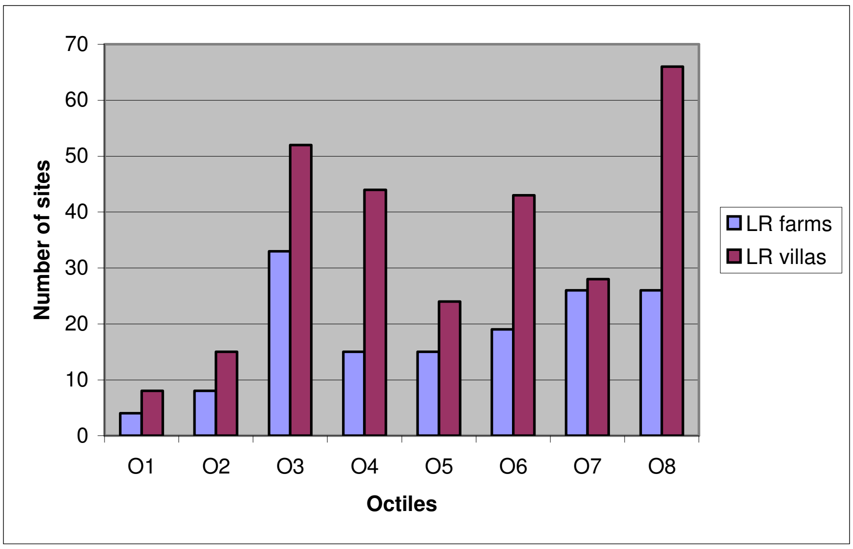


Figure 5.31 Bar chart showing number of sites in each octile range (Late Republican model 4a)

The comparison of sites follows almost exactly the same pattern as the previous Late Republican olive model. Villas are most numerous in O_8, but have more variability in O_{3-7} than the previous model, with dips in site numbers in O_5 and O_7. The largest number of farms is in O_3, though numbers in O_7 are lower than the previous model.

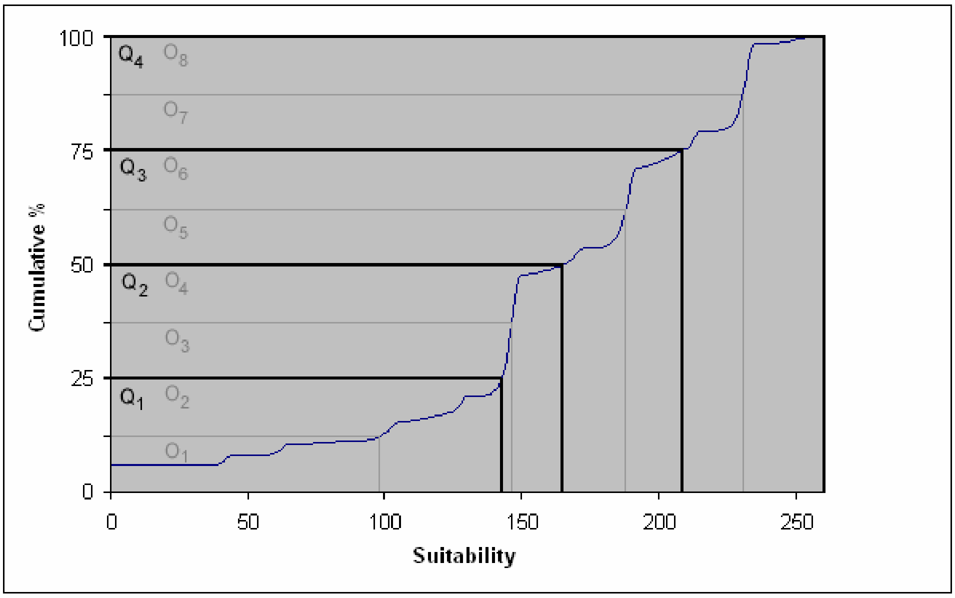


Figure 5.32 Graph showing quartiles and octiles of olive suitability distribution (Early Imperial model 4b)

The graph (Figure 5.32) shows that the overall curve for the Early Imperial data is the same as the Late Republican, with the same quartile and octile distribution and, again O_3 was the most dominant category of land suitability.

Table 5.26 Number of Early Imperial sites in each olive suitability category (quartiles)

Quartile range	Suitability rating	Inter-quartile range	EI farms	EI villas	% EI farms	% EI villas
Q_1	0-142	142	41	52	28.08	18.57
Q_2	143-164	21	212	225	145.21	80.36
Q_3	165-208	43	120	159	82.19	56.79
Q_4	209-255	46	162	217	110.96	77.50

Table 5.27 Number of Early Imperial sites in each olive suitability category (octiles)

Octile range	Suitability rating	Inter-octile range	EI farms	EI villas	% EI farms	% EI villas
O_1	0-98	98	16	17	10.96	6.07
O_2	99-142	43	25	35	17.12	12.50
O_3	143-146	3	128	119	87.67	42.50
O_4	147-164	17	84	106	57.53	37.86
O_5	165-187	22	48	65	32.88	23.21
O_6	188-208	20	72	94	49.32	33.57
O_7	209-229	20	49	48	33.56	17.14
O_8	230-255	25	113	169	77.40	60.36

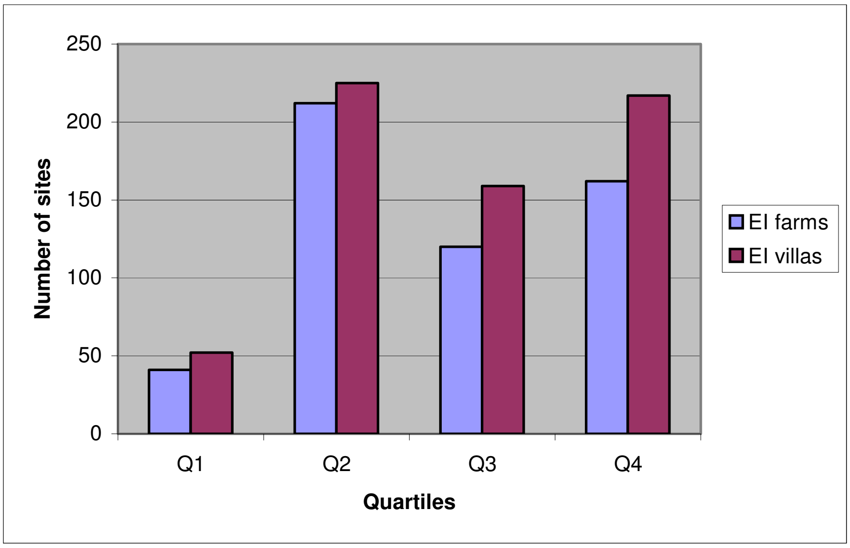


Figure 5.33 Bar chart showing number of sites in each quartile range (Early Imperial model 4b)

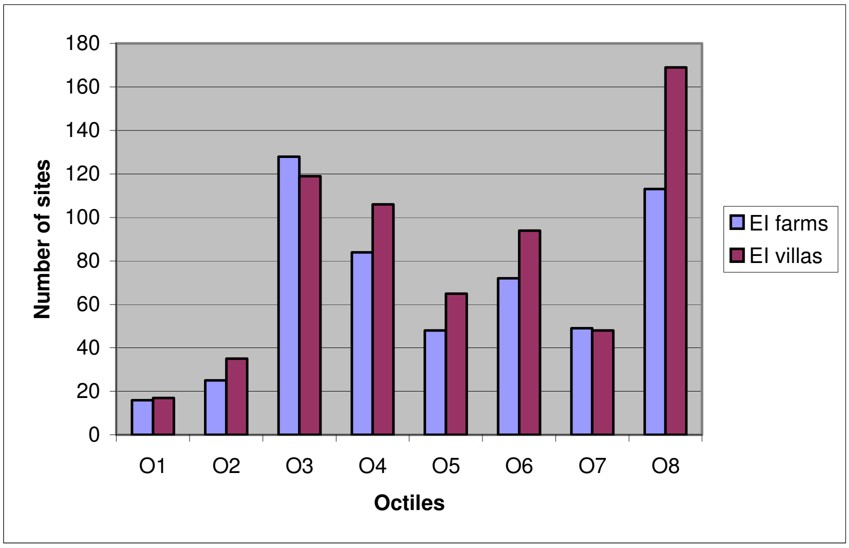


Figure 5.34 Bar chart showing number of sites in each octile range (Early Imperial model 4b)

The distribution of sites on the Early Imperial model shows the same patterns as expected (Tables 5.26-5.27 and Figures 5.33-5.34). With the increased sample size, however, we are now getting the maximum number occurring in Q_2 for both farms and villas. The octile divisions also show the same pattern as the Late Republican analysis, with the exception that, whilst the maximum number of villas is in O_8, the maximum number of farms occurs in O_3. There are also peaks in farm numbers in O_6 and O_8.

What this analysis has shown overall was perhaps to be expected given the results of the wheat suitability analysis (Section 5.3). Given that the suitability maps showed that different regions were suitable for wheat and olive cultivation, and that many of the sites were situated in the areas suitable for wheat, it was to be expected that not as many sites would be located on the uppermost olive suitability categories. What we are therefore probably seeing in the peaks in lower suitability categories, are those sites possibly located to take advantage of good wheat lands. However, large numbers of sites also appear in the top categories. This is likely to indicate those areas that are equally suitable for both wheat and olive cultivation.

Also, we are dealing with the results of survey bias: it must be remembered that the suitability map showed the Sabine region to be suitable for olive cultivation. As few areas of the Sabina have been subject to field survey, therefore fewer sites are likely to occur on this type of land (i.e. hillier and with thinner soils). However, where this analysis is interesting, is in the comparison between wheat and olive cultivation.

5.5 MCE for vineyards

Vines are not grown extensively in the study area as a single crop (Figure 5.35), but by creating a suitability map, it may be possible to see the reasons why this was, and still is, the case. The best type of soil for vine production is very well drained, which may be one reason why these are often grown on hill slopes. To illustrate, in France and Germany the soils which produce the very high-quality wines contain large amounts of stone, gravel or shale (White 1988: 227). This is reflected by Virgil (*Georgics* 2.346ff) who advises that stones or shells be added to the soil. Columella's recommendations for vines are that:

> *the best soil … is neither too compact nor loose, but closer to the loose type; neither poor nor excessively rich, but nearest to the fertile kind; neither flat nor steep, but like plain-land with a rise; neither dry nor wet, but moderately moist … and that neither bitter nor brackish.*
> *Rust*. 3.1.8-10

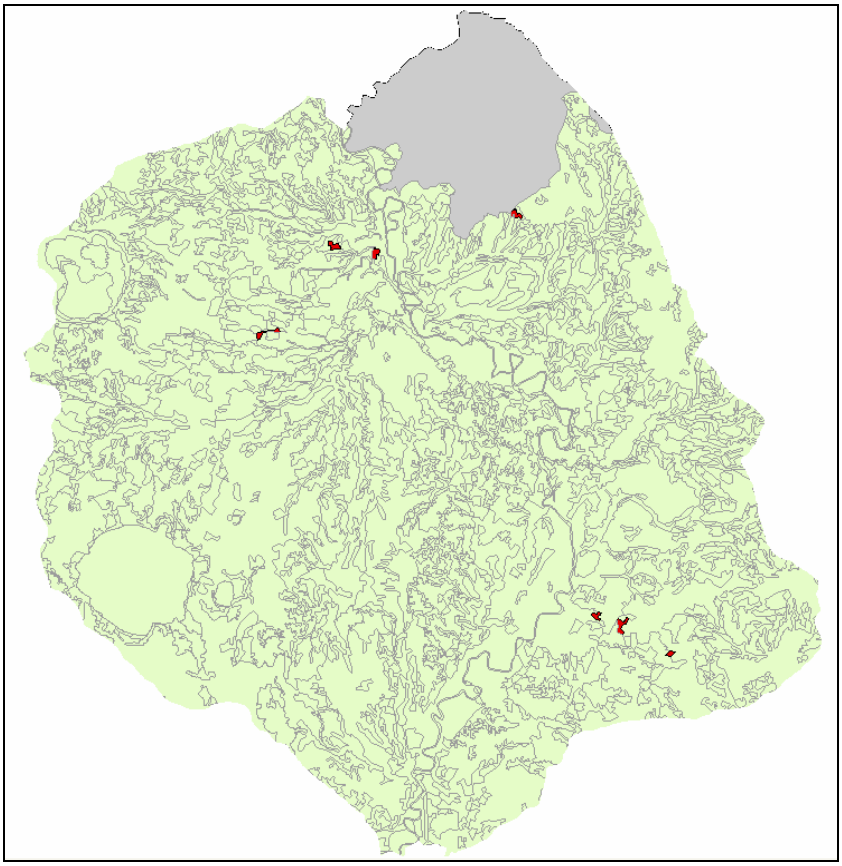


Figure 5.35 Land use map showing only vineyards in red

This passage implies that the richest soils are not always the most appropriate, and that sloping ground is considered suitable. He also recommends a friable soil, not too compact as being best for vines.

Virgil also outlined suitable land for viticulture:

> *But where the soil is rich and rejoices in sweet moisture,*
> *Or a level expanse grown deep with grass all lush and verdant,*
> *Such as we often find when we look down into a fold*
> *Of the hollow hills (for becks flow hither bearing alluvial*
> *Soil from the heights above), or an upland facing south*
> *Where the plough is baulked by bracken:-*
> *Such sites as these one day produce superlative vines*
>
> *Georg*. 2.184-190

His advice seems to favour rich and moist soils on level low-lying ground or on upland sites. Virgil also advises to "a*void sloping your vineyard towards the setting sun*" (i.e. west-facing slopes, *Georg*. 2.298).

Cato's advice varies according to which type of grape is cultivated:

> *Choose soil for laying out a vineyard by the following rules:- In soil which is thought to be best adapted for grapes and which is exposed to the sun, plant the small Aminnian, the double eugeneum, and the small parti-coloured; in soil that is heavy or more subject to fogs plant the large Aminnian, the Murgentian, the Apician, and the Lucanian. The other varieties, and especially the hybrids grow well anywhere.*
>
> Cato de Agr. 6.4

Varro mostly quotes from Cato, though does briefly discuss land suitable for vines:

> *Vines [are best adapted] to the hills*
>
> Varro Rust. 1.6.5

> *In thin soil … you see no sturdy trees, nor vigorous vines*
>
> Varro Rust. 1.9.5

Pliny the Elder also discussed vine cultivation in great detail:

> *Virgil condemned their being planted looking west, but some have preferred that aspect to an easterly position, while most authorities, I notice, approve the south; and I do not think that any hard and fast rule can be laid down on this point … some people make the question of aspect depend on the nature of the soil, letting vines planted in dry situations face east and north and those in a damp one south*
>
> Pliny the Elder *NH* 17.19-22

> *The chalky soil in the territory of Alba Pompeia and a clay soil are preferred to all the other kinds for vines, although they are very rich, a quality to which exception is made in the case of that class of plants. Conversely the white sand in the Ticino district, and the black sand found in many places, and likewise red sand, even when intermingled with rich soil, are unproductive.*
>
> Pliny the Elder *NH* 17.25-26

> *Some varieties of vine … draw nourishment from frosts and clouds*
>
> Pliny the Elder *NH* 17.29

All criteria outlined by the ancient writers were put into a table to see if any recommendations followed the same advice (Table 5.28, page 226), as well as to compare with the location of modern vines in the study area. Modern vine cultivation occurs primarily on volcanic geology (see Table 5.29, page 235), but also on some sandy and clay geology types. However, the land use map only highlights areas of monoculture of vines, and therefore much production that takes place using intercultivation techniques, cannot be included here.

Table 5.28 Suitability of soils for viticulture according to the agronomists

	Suitable	Unsuitable
Cato	Exposed to the sun	
Varro	Hills	Thin soils
Columella	Marginally friable soil	Very compact
	Marginally fertile	Very loose
	Medium slopes – plain land with a rise	Very fertile
	Moderately moist	Very poor
		Flat
		Steep
		Dry
		Wet
		Bitter or brackish soils
Virgil	Soils with stones or shells added or included	West-facing slopes
	Rich soil	
	Moist	
	Level ground	
	South-facing uplands	
Pliny	Most prefer south-facing, but any aspect may be suitable	Sand
	Chalky soil	
	Clay soil	

Table 5.29 Geology types used for modern vine cultivation

Geology type	Hectares of vineyard
Quaternary and recent alluvium	8.55
Nappe debris, weakly or not cemented	1.98
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	3.06
Sands, often with concretions	74.25
Tuff, pozzolana and ignimbrites	164.43

Modern vine cultivation also occurs in fairly low-lying regions, the range of altitudes utilised being from 33-309m asl. The ancient sources do not really mention any restrictions on altitude, but the mean altitude of 142m asl would seem to imply modern preference for low-lying regions. The ancient sources do, however, mention slope, and Columella recommends slightly sloping ground that is neither flat nor steep, whilst Virgil does suggests that level ground is suitable. In modern cultivation the range of slopes utilised range from 1-36% (i.e. from level to steep, according to the Soil Survey classifications (Soil Survey Division Staff 1993: chap. 3, tab. 3.1). The mean slope percentage is 7.7%, classed as gently sloping. Aspect is problematic as Pliny states in the passage above that, despite the common recommendation for south-facing slopes, suitable aspects can vary depending on soil type and other environmental factors. This is supported to some extent by the location of modern vines in the study area, as the most frequently used aspect is actually north-east, whilst east-, south-east-, and south-facing slopes are used less frequently.

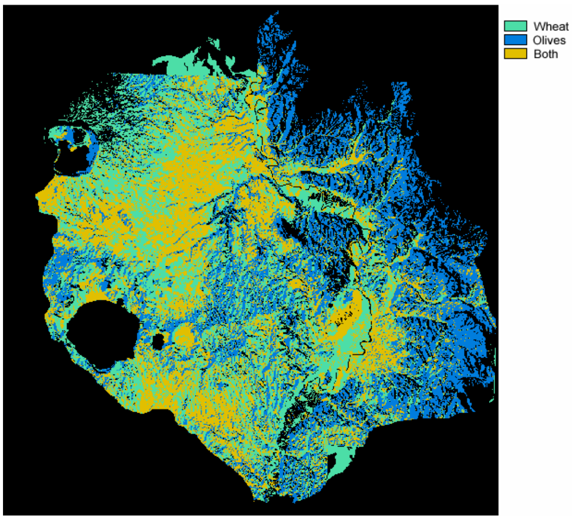
As we cannot use the modern information in modelling in this instance, it was realised that the information given by the ancient writers was too varied to produce a useful model. The fact that Cato states that some varieties will grow anywhere (above, *de Agr.* 6.4) also negates the need for a model in this instance.

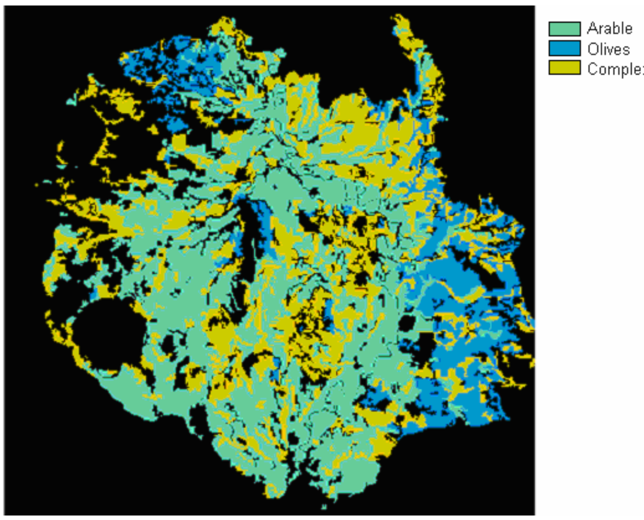
5.6 MCE for intercultivation

The intercropping of cereals was a system that had been in existence in Italy since before 600 BC, introduced first in the Etruscan regions (Spivey and Stoddart 1990: 62; Barker and Rasmussen 1998: 193). In the study area this is still reflected in modern agricultural practice, particularly in the Sabine region, with olives and cereals frequently cultivated together. By growing crops together in this fashion, each individual crop yield is reduced, yet the overall yield of the area cultivated increases (see Chapter 8 for discussion of yields).

It is not possible to realistically determine which crop combinations would have been chosen in which areas, whether olives and cereals, vines and cereals, olives and legumes, and so on. However, the previous models (Section 5.3 and 5.4) are useful in showing how much of the study area is suitable for certain agricultural economies (wheat or olives), and a comparison will demonstrate spatially where this best land is, and which Roman sites were likely to follow particular regimes. This section will approach the combination of cereals and olives, but not cereals and vines due to the lack of suitable evidence for vineyards.

Using the equally weighted, Early Imperial model, the top two quartiles for wheat (Section 5.3.2) and oleoculture (Section 5.4.2) were isolated and overlaid to show which areas were most suitable for which crop, and if any areas overlapped. This was then compared to the modern land use map (Figure 5.36).





a. **b.**

Figure 5.36 a) results of the comparison of arable and olive models, b) position of arable, olives and complex agriculture in the modern land use

Results showed that there were some areas of overlap, but that they were not significant. The overlap consisted of only 21% of the modern complex agriculture. This was also carried out with the weighted models (Sections 5.3.2 and 5.4.2) and a similar result was obtained, with a 22% overlap.

These analyses were run again, this time using the top three quartiles. This gave an overlap of 63% and 58% for the equally weighted and weighted models. This was not surprising given that the models are classifying 75% of the area. However, the fact that many areas were still not overlapping could be interpreted in a number of ways. Most importantly, modern cultivation may not reflect ancient practice. Where the Roman farmers chose to practice intercultivation may not be the same types of areas for any number of reasons. Secondly, the practice of intercultivation was sometimes carried out on poorer land to increase returns (see Chapter 6) and so this model may not be targeting the right types of areas. Further analyses discount the comparisons with modern data, due to potential problems in using such datasets. The areas of potential intercultivation highlighted by the models in this section, however, will be used, particularly in Chapter 8, where specific landholdings are analysed to determine potential production figures.

5.7 MCE for pastoralism/meat production

The consumption of animal products and meat was an important part of the Roman diet, and Roman husbandry practices receive a great deal of attention in the ancient sources (e.g. Varro *Rust*. Bk. 2 and Columella. *Rust.* Bk. 7), yet the zooarchaeological evidence available for study is limited to fewer than 100 sites in Roman Italy (MacKinnon 2001: 651).

Pigs were the only animals in Roman Italy to have been bred purely for their meat, and all of the excavated sites yielded pig bones. Compared to cattle, sheep and goats, they were generally the most well-represented animal in central and northern Italy (MacKinnon 2001: 656; see also Barnish 1987). They were a common animal for sacrificial offerings (White 1970a: 321) and played a very important role in the diet of the Romans, particularly the army. Pigs are known to have been the most important source of meat, at least in the later Roman period (*Codex Theod*. 14), and the pork dole of Aurelian, for example, issued 10,000 kilograms of pork daily for the urban poor (Barker 1985: 35). Cato's lists of equipment and manpower for both an oliveyard and vineyard included a swineherd (*de Agr*. 10.1, 11.1), and the predominance of the pig in Italy is highlighted by Varro who argued that,

> *…who of our people cultivates a farm without keeping swine? and who has not heard that our fathers called him lazy and extravagant who hung in his larder a flitch of bacon which he had purchased from the butcher rather than got from his own farm?*
>
> *Rust*. 2.4.3

Though Varro may be biased towards larger-scale villas, there is also plenty of comparative evidence to support the production of pigs on lower-status sites. In Europe there are traditionally two ways of rearing pigs – either on a farm with occasional foraging or pannage, or left to roam wild in woodland until rounded up (Delano Smith 1979: 220; Barker 1985: 35). This is supported to some extent by the sources where two levels of pig production are evident: a small herd or single pig kept on farms and fed with scraps and litter, and large-scale breeding for the market as described in detail by the agronomists (e.g. Varro *Rust*. Bk. 2; MacKinnon 2001: 658).

Columella (*Rust.* 7.9.6) stated that the best feeding grounds for pigs are woodland (see also Martial 11.41; Ulpian *Dig*. 19.5.14.3; Strabo 5.1.12), and this has remained the case up until the modern period. The modern situation in South Etruria is for most villages to have areas of woodland maintained nearby in order to provide pannage (Potter 1979: 22).

> *Pigs can make shift in any sort of country wherever situated. For they find suitable pasture both in the mountains and in the plains, though it is better on marshy ground than on dry. The most convenient feeding grounds are woods covered with oaks, cork-trees, beeches … for these ripen at different times and provide plenty of food for the herd almost all the year round.*
>
> Columella *Rust.*7.9.6

> *As this animal feeds chiefly on mast [acorns, beechnuts, etc] and next on beans, barley and other grains, this food produces not only fat but a pleasant flavour in the flesh.*
>
> Varro *Rust.* 2.4.5

> *…the forests have acorns in such quantities that Rome is fed mainly on the herds of swine that come from there.*
>
> Strabo *Geog*. 5.1.12

The fact that pigs can live in diverse environments, and also eat a wide variety of foods, makes the animal very versatile for the smallholder to maintain a small herd or single animal (White 1970a: 316). It has been argued that pigs are the most functional animals to keep, given that they are cheap to maintain and they contribute much to the diet – a peasant would have to be extremely poor not to be able to afford to keep one pig, given that it can survive on scraps (Delano Smith 1979: 219).

Specialised pig farming also occurred on a larger scale with herds of up to 150 animals (Varro *Rust*. 2.4.22). These herds could be kept on pastures during the summer but would be stall-fed in the winter (Varro *Rust*. 2.4.6-7), and the agronomists give specifications for the construction and maintenance of pig-sties (Varro *Rust*. 2.4.14-15; Columella *Rust*. 7.9.9-10).

Etruria was not known as a key centre of pig production – according to MacKinnon (2001: 659) key areas were Milan (Varro *Rust*. 2.4.11), Cisalpine Gaul (Strabo 5.1.12; Polybius 2.15), Campania, Bruttium and Lucania (*Codex Theod*. 14.4.10.3; Cassiodorus *Var.* 11.39). It is possible then that herds would have been smaller in this area. The only large assemblage of pig bones in the study area comes from Monte Gelato, where approximately 212 individual specimens were excavated (King 1997: 385, tab. 66). This, however, covers a long period of deposition throughout the Early Imperial until the Late Roman period and so we cannot know how large the herds were likely to be have been.

So, is it therefore possible to model where pigs were likely to have been kept? Given that pigs could be kept in such diverse environments and survive on such a variety of foods it would mean that the entire area would be suitable, thereby rendering a multi-criteria analysis meaningless. Instead, pig production is looked at in more detail in Chapter 6 to determine its likely contribution to the diet, based on different herd sizes.

Varro gives a lot of attention to ranching and large-scale sheep-raising, but sheep had their place on a smaller mixed farm also. For example, Cato, though not including much detail on sheep rearing, does recommend keeping 100 sheep for an oliveyard (*de Agr*. 1.10). It has been suggested that these would have been stall-fed and their manure used for cultivation (White 1970a: 304). In an arable system, sheep could be grazed on stubble with the dual purpose of manuring the ground ready for the next season of cultivation (White 1970a: 310). Small-scale pastoralism was thought to have been usual throughout most of Italy. This could have been either integrated with arable farming, as above, or a necessary economic pursuit in areas not suitable for cultivation of certain crops (Morley 1996: 155; MacKinnon 2004a: 58).

This has been supported by results from the surveys in Rieti and Biferno (Barker 1995a; Coccia and Mattingly 1992).

For large-scale sheep rearing, the practice of transhumance was common in Italy. In this system the sheep would only be stall-fed during lambing and they would ordinarily graze in seasonal pastures (MacKinnon 2004a: 56-58; White 1970a: 306). Varro's flocks were wintered in Apulia, moving to the mountains of Rieti during the summer months (*Rust*. 2.2.9f). This practice has drawbacks for the peasant farmer – notably that they would need a permanent shepherd to move with the flocks, and secondly they would lose out on the valuable manure produced. Smaller peasant farms are therefore more likely to have had smaller flocks in a mixed system, and even Columella refers to sheep stalls and the winter diet (*Rust*. 7.4.2), implying that herds could be kept locally for larger estates.

Goats, on the other hand, could not be grazed in the same way, as they were destructive due to their diet of leaves, buds and young shoots, and consequently required constant attention (White 1970a: 314; Delano Smith 1979: 225). Their preferred habit is scrub, and goats were said to be best pastured in rough wooded districts (Columella *Rust*. 7.6.1). Maximum recommended herd size was around fifty animals (Varro *Rust*. 2.3.10).

Speaking of all ranching animals, Virgil mentions suitable areas to keep such herds.

> *But if your business be rather the keeping of calves and cattle,*
> *The breeding of sheep, or goats that burn up all growing things,*
> *You should try the woodland pastures and the prairies of rich Tarentum*
> *And plains such as unlucky Mantua has lost*
> *Where snow-white swans among the river weeds are feeding:*
> *Here neither springs of water nor grass will fail your flocks*
>
> Virgil *Georg*. 2.195-200

Evidence for cattle is also limited. Domestic cattle tended to be stalled and their manure used for fertilising the cultivated land (White 1970a: 274). The modern situation in the study area has cattle pastured on river-side meadows during summer and given fodder over winter (Potter 1979: 22). Horace states that cows were pastured among the "*grassy meadows with meandering streams and marsh willows*" around upland Sabine farms (Horace *Odes* 2.5.1ff)

So, is it therefore possible to model where grazing was likely to have taken place? This is extremely complex. Areas suitable for pastoralism tend to be more marginal areas or meadows and as such could possibly be modelled. Good access to water is essential in order to keep the animals healthy, and access to drove-roads or markets is likely to have impacted on the location of feeding grounds. Aspect, altitude and slope were unlikely to have had an impact on the location of suitable areas. Areas of woodland are likely grounds for pannage. For sheep, however, thin soils over limestone tend to have poor water retention, and therefore produce dry rough grazing areas in hillier areas (Finke *et al.* 1994: 91).

Overall, creating a model for suitability for animal rearing is problematic as it is difficult to quantify the information available. It would be necessary to rely on the modern land use map to identify areas of woodland, meadow or scrub, which may have been used for animal grazing or pannage. Due to the difficulties it was decided not to model this particular economic strategy in this instance. Instead, it was decided to focus on crop production, whilst the possibility of small-scale meat production in a mixed economy is incorporated within the discussion of yields in Chapter 6 and the consumption models of Chapter 8.

5.8 The impact of the models on the interpretation of known Roman sites

As evaluation was possible for most crop combinations it was possible to compare this information to the known Roman rural villa and farm sites. This means that areas could be isolated for explicit use of one or the other economies, aiding in interpretation of the possible function of some sites known from the database. By extracting the underlying value of each suitability map, each site can be assigned a likelihood of following a particular economy on a scale from 0-255 (least to most suitable). For example, is the site more suited to oleoculture than arable? Of course, this is a hypothetical exercise, as any results do not mean that the site actually followed this economy. This is particularly the case where an estate or smaller agricultural unit would have contained a variety of land types, and most farmers follow a mixed farming economy to minimise risk (see Chapter 6). However, this would highlight those areas most suitable for a specific regime. Importing the raster suitability files into *ArcGIS* means that the point files for villas and farms could be viewed as a layer over these images. This means that individual sites could be assessed regarding their territory and the quality of land within.

The analysis carried out in this chapter has some obvious limitations. The main drawback with the method is that the analyses refer only to small central area of what was probably a much larger farmed territory. The process analyses the cell where the site is situated, in this case the cell has a 30m resolution (a 'territory' of only $900m^2$ or 0.4 *iugera*, see Chapter 4.12). It may therefore follow that the point at which the site is located has a low suitability, but is immediately adjacent to good agricultural land. A better option would therefore be to carry out this procedure on polygon files outlining possible estate boundaries and assessing the range of suitabilities within. This is where the following chapter improves on these models. By assessing the potential production of differently-sized farms and villa estates, this differential land quality is taken into account. Creating ‘yield maps’ for different economies tests the production ability of these agricultural units and consequently the demographic effects of different yields.

6 CROP YIELDS IN THE ROMAN PERIOD AND AGRICULTURAL MODELS

The quantification of crop yields and consumption is the next factor to be considered in this analysis. This analysis follows a strategy that has been used within both ancient history and archaeology for the study of population subsistence (see Section 6.4). The basic procedure is to assess the amount of food available in a given area alongside nutritional requirements in order to attain a potential population figure, or an optimum size of landholding. This may be approached both on a small-scale (looking at individual farms and villas) and on a large-scale (looking at the population of Roman Italy as a whole). These have included the adoption of many assumptions by historians (discussed below) regarding how much land was needed to support a family and what percentage of the country was being utilised for agricultural purposes, with the aim of establishing probable population figures.

A similar type of assessment is carried out here. In this chapter, evidence for historical yields within the study area is considered, and agricultural models posited by other scholars are compared. Different agricultural regimes known from a variety of sources are studied and used to determine potential crop yields and agricultural practice. This is built upon in Chapter 7 where the study of nutritional requirements, in conjunction with the yields established here, is used to model likely subsistence in the study area. Again, it must be remembered that the accuracy of the ancient sources is not the issue in this respect, though comparison with modern yields is interesting in its own right. Instead, this chapter compiles the range of ancient thought on agricultural yields in order to model the implications in Chapter 8.

6.1 Evidence for historical crop yields

The first stage in the analysis of potential Roman crop yields is to assess both ancient and historical production statistics for Italy. The majority of available information is in relation to crop yields of cereals – there is much less information regarding the production of crops such as vines and olives, and even less for the productivity of pastoralism and animal-rearing for meat. Once possible yields were known, estimates of productivity and consumption were then approached.

6.1.1 Cereals

The evidence for crop yields from antiquity is varied, and as such their often contradictory nature (Evans 1981: 429) could be taken as highlighting their inaccuracy. The scant ancient references we have for ancient yields in this area range from Columella's cereal yield of 4:1 for the whole of Italy (*Rust*. 3.3.4) to the exceptional yields of 100:1 for Sybaris mentioned by Varro (*Rust*. 1.44.1) and Pliny the Elder (*NH* 18.94-5). For Etruria, an area noted for its fertility, Varro (*Rust*. 1.44.1) gave maximum yields of 10-15:1. The remaining passage is from Cicero (*Verr*. 2.3.112) where he claimed a yield of between 8-10:1 in the land surrounding Leontini in Sicily.

The reliability of these yields has been discussed at length by various scholars (e.g. White 1963; Spurr 1986a; White 1970a; Brunt 1972; Evans 1981; Duncan-Jones 1982). White, for instance, argued that similarities between early 20th century yields for Sicily and Tuscany, and the Roman yields of Varro and Cicero (8-15:1) demonstrated their reliability (White 1963: 208-209). Columella's yield of 4:1, though low, could be considered a more appropriate average for Italy as a whole, incorporating areas of high and low fertility. An alternative view was that this yield referred to cereals produced from intercultivation with vines, which would certainly cause a lower yield per unit area (White 1963: 209). Here, however, we are not trying to deduce an overall yield for the country. That would be a near impossible task given the huge differences in topography, climate and land quality, as well as different economic strategies. The fact that yields of ten and fifteen-fold are given as exemplars of high yields also implies that the rest of the country was not as productive as these regions. It has therefore been argued that such yields were therefore beyond the capability of most Roman peasant farmers (Evans 1981: 434). However, given that the high yields in question refer to this study area, these may be modelled further to gauge likely production potential.

Another argument against high yields in antiquity is that it has been asserted that yields in the ancient writers refer to yield per plant rather than yield per unit area. This is thought to indicate lower overall production. Spurr (1986a: 83) illustrates this idea by using the 100:1 Sicilian yields – it could refer to 100 ears of wheat rather than 100 plants from a single seed. In this way, we should be guarded about how we utilise the statements of the agronomists regarding agricultural yields, as overall production may be lower than implied in the sources (Garnsey 1999: 26-27). However, by knowing the sowing rates used, and the likely number of plants produced this is less problematic, as we may still calculate the overall weight of the yield. This may also be counteracted by the use of a number of different models testing the production of different yields.

Yields vary not only regionally, but also from year to year, and so it is difficult to pin down one specific yield for an area over a period of time. However, we can say that certain areas are likely to produce more than others, given the nature of the fertility and other environmental variables, and produce mean production figures. The regions of South Etruria and Sabina are not uniformly fertile, even though it may be tempting to infer this from the ancient sources. Therefore some assessment of factors that would have affected yields was carried out for the study area. Based on the plot sizes determined in Chapter 3, different yields could be tested to calculate how many people could subsist on agricultural units of these sizes.

Due to this dearth of detailed contemporary information, much of the data used in this model comes from post-Roman sources. Although subject to the same problems as using earlier data, it is still possible to identify some patterns, which will be discussed in greater detail later. The aim was to incorporate all the different factors that affect yield into a digital 'yield map' of the study area, which would then be used to estimate possible production of the area. Historical data for yields was derived from a number of sources, and these have been laid out in Table 6.2.

1.1.1.1 Sowing rates

The amount of wheat produced is dependent on the amount of seed sown, and so in order to quantify how much was produced according to the given yield it was necessary to establish the amount of seed sown per unit of land. Sowing amounts can vary both over time and space due to aspects such as soil quality and technical differences. For example, in the Roman period the broadcast sowing method was used which can be imprecise and is highly dependent on the skill of the sower in distributing seed regularly (White 1970a: 179). However, from the sources available a fixed rate was established with which to model productive potential.

Five *modii* per *iugerum* (135kg/ha) was advocated by the agronomists as a typical sowing amount for a reasonable crop return (Varro Rust. 1.44.1; Columella Rust 2.9.2), whilst Cicero (*Verr*. 2.3.112) speaks of sowing at six *modii* per *iugerum* (162kg/ha). Columella (*Rust*. 2.9.1-2) also notes that some people sow with eight to ten *modii* per *iugerum* (216-270kg/ha). However, both Columella (*Rust*. 2.9.2-6) and Varro (*Rust*. 1.44.1) suggest that the amount sown really depends on local variables, such as soil, topography, and intensity of cultivation.

The five *modii* sowing rate was used with success at the experimental Butser Iron Age Farm in Britain (Reynolds 1981). This rate was also compared to statistics cited by Spurr (1986a: 85-88) for the region of Basilicata in Italy from 1909-1913. These statistics are quite variable, ranging from 128-142kg/ha but, when averaged, also give a sowing amount of 135kg/ha (Table 6.1). As this is equivalent to a five *modii* per *iugerum* sowing rate, it was decided to use this as an appropriate standard rate within the model. Ten *modii* per *iugerum* was also modelled in order to determine the maximum return.

Table 6.1 Sowing amounts derived from Rossi Doria (1963: 108-9, in Spurr 1986: 88, tab. 2)

Location	Yield	Yield in quintals / ha	Kg / ha	Amount sown in kg
Basilicata - Whole region 1909	8:1	10.3	1,030	128.75
Basilicata - Whole region 1910	4:1	5.7	570	142.5
Basilicata - Whole region 1911	6.5:1	8.8	880	135.38
Basilicata - Whole region 1912	5:1	6.8	680	136
Basilicata - Whole region 1913	8:1	10.6	1,060	132.5
		Mean sowing rate:		135 kg/ha

1.1.1.2 Crop yields

Comparative data for crop yields has been collated from a variety of sources, and the historical yield data from the study area is detailed below (Table 6.2; the full list is in Appendix V.1). This includes yields given for larger areas in which our study area is located, for example Latium in the 19th century is taken to mean the region of modern Lazio, and yields for the whole of Italy are also included. This table shows the amount of wheat produced per hectare (assuming the sowing ratios from the ancient sources) according to the yields derived from the sources. From the table we can see that an average yield for Latium is between 6-7:1 (810-945kg/ha). Overall production ranges from 540 up to 2,050kg/ha, according to the ancient sources. Even the modern (although pre-mechanisation) figures imply a yield only slightly higher than Varro's figures with production at a maximum of 2,230kg/ha in 1963.

The Italian yields in Appendix V (Table V.1) were plotted as a bar graph to show how frequently they were recorded (Figure 6.1). This graph shows that, within Italy and based on yields from antiquity to the modern period, yields range from an absolute minimum of 1.7:1 up to 20:1. The 100:1 reference is discounted, as it is obviously an outlier in the distribution. The majority of statistics show yields of between 4:1 and 10:1, 5 and 6:1 being most frequent. Yields of between 10-15:1 were also not uncommon.

Table 6.2 Historical yields for the study area and Italy overall

Source	Location	Yield	Modern yield equivalent in kilograms per hectare: 5 modii per iugerum	Modern yield equivalent in kilograms per hectare: Unknown sowing ratio
Columella *Rust.* 3.3.4	Italy 1st century	4:1	540	-
Varro *Rust.* 1.44.1	Etruria c.37 BC	10-15:1	1350-2050	-
Porisini 1971	Latium, 1832-3 - Sora, in the hills above the Sacco river plain	3.14:1 - 5.2:1	423.9-702	-
Porisini 1971	Latium, 1832-3 - Gaeta, on the coastal plain	5-7.5:1	675-1012.5	-
de Tournon 1855	Latium, early 19th century - best soils	10:1	1350	-
de Tournon 1855	Latium, early 19th century - good soils	7:1	945	-
de Tournon 1855	Latium, early 19th century - medium soils	5:1	675	-
de Tournon 1855	Latium, early 19th century - poor soils	4:1	540	-
Schmidt 1936: 650, tab. 3	1909-1914 - Central Italy			810
	1921-1925 - Central Italy			890
	1926-1930 - Central Italy			1010
	1931-1935 - Central Italy			1070
Naval Intelligence Division 1945c: 519-523	1938 - Rieti	-	-	938
Naval Intelligence Division 1945c: 519-523	1938 - Rome	-	-	1297.63
White 1963: 211	1959 - Italy	-	-	1800
FAO	1961 - Italy	-	-	2181.5
Mean yields			933.04	1,116.52
Mean yield ratio			7:1	12:1

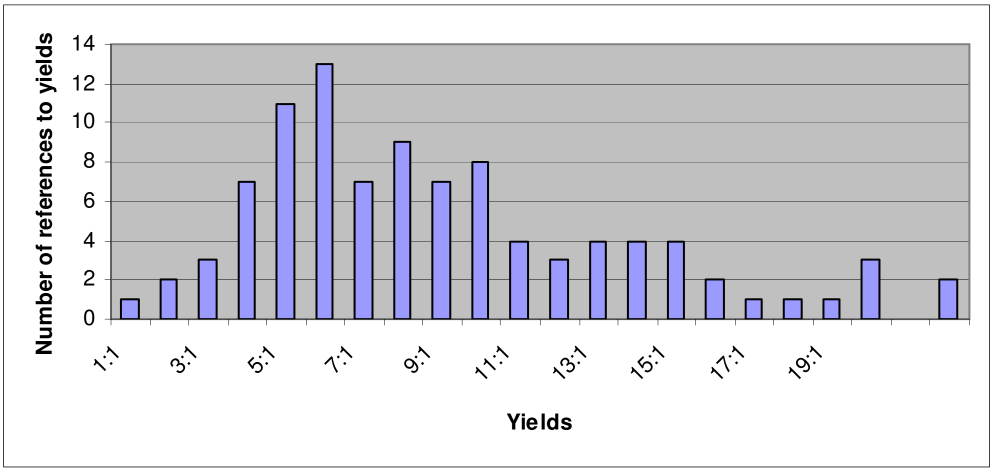


Figure 6.1. Chart showing the number of references to certain yields for Italy from antiquity to the modern day (based on Appendix V, Table V.1)

These figures disguise both locational and seasonal variability, however, some studies collected by Spurr do give an idea of the difference a varying topography can make on yields. All the entries showing topographical differences showed that, invariably, hills and mountains yielded less than plains and river terraces (Table 6.3).

Table 6.3 Yields from a) 10th century Emilia Romagna and b) late 18th century Tuscany, showing differences in yields according to topography (after Spurr 1986: 86, tab. 2)

	Source	Location	Yield	Modern yield equivalent (kg/ha)
a.	(Fumagalli 1978: 71)	"in the plain"	3.3+:1	445.5
		"on a higher river terrace"	2.8:1	378
		"in the hills"	2:1	270
		"in the mountains"	1.7:1	229.5
b.	(Young 1794: 157, 209-215)	"in the plains"	8:1	1080
		"in the deposits of rivers, or spots remarkably rich"	12,15, or even 20:1	1620-2700
		"in the low hills" after legumes	9-10:1	1215-1350
		"in the low hills" after wheat	6-7:1	810-945
		"in the low hills" after wheat	3-4:1	405-540

In the examples shown it can be seen that, in general, a reduction in yield took place when cultivating on hilly ground rather than river terraces or gently sloping plains, with the reduction becoming more prominent in mountainous areas. The yields from the hills also demonstrate diminishing returns when sowed in rotation with legumes. According to the data from Emilia Romagna, the reduction in yield from a plain to a hill was from 3.3:1 to 2:1. This yield decreased further to 1.7:1 in the mountains. In Tuscany, however, the plains appeared to be yielding slightly less than the low hills. This, however, is due to the practise of rotation, which we can tell from the description – "*after legumes*" or "*after wheat*". If one were to average the returns for the three seasons, an average yield of 6.5:1 is achieved.

The wheat yields shown demonstrate the variation in production over time as well as regionally. They do, however, also show that in general Italy has produced fairly consistent yields since the Roman period. Yields fall within a range of approximately 2:1 up to 20:1, though dominated by the range 4-10:1. A subset of these yields will therefore be used in Chapter 7 for further analysis.

6.1.2 Olives

In contrast to the large quantity of historical data for wheat production, other crops such as olives (*Olea europaea*) are much more difficult to quantify. Olive yields are highly variable and there is little evidence for yields per tree or per unit area, either in antiquity or even for modern Italy other than overall national production statistics. Of the 585 varieties grown in modern Italy, the study area has three main olive cultivars – Raia, Moraiolo and Rosciola – and production differs between varieties (Bartolini *et al.* 2005). Olives are generally biennial in their production, with crops regularly alternating between good and bad (Osborne 1987: 45; Forbes and Foxhall 1978: 37), though the three main cultivars mentioned above vary between "alternate poor" (Raia), "alternate good" (Moraiolo) and "constant good" yields (Rosciola) (Bartolini *et al.* 2005). The generally biennial nature of olive crops was also noted in antiquity though actual production figures are rare.

> *…and the olive tree, the queen of all trees, requires the least expenditure of all. For, although it does not bear fruit year after year but generally in alternate years, it is held in very high esteem.*
>
> Columella *Rust*. 5.8.1-2

Further problems arise in determining yields due to differences in planting strategy. The wide variety of schemes noted from the ancient authors has been assessed by Mattingly (1994: 93, see also Table 6.4).

Table 6.4 Comparison of tree spacing from the Roman authors (after Mattingly 1994: 93, tab. 1)

Source	Spacing in Roman *pedes*	Spacing in metres	Approx trees per hectare	Region	Intercultivation
Cato *de Agr.* 6.1	25	7.4	180	Italy	
	30	8.9	126	Italy	
Columella *de arb.*17.3	60	17.8	30	Spain? Italy?	Yes
Columella *Rust.* 5.9.7	60 x 40	17.8 x 11.8	47	Spain? Italy?	Yes
	25	7.4	180	Italy	
Pliny *NH* 17.93-94	25	7.4	180	Italy	
	30	8.9	120	Italy	
	45	13.3	56	Africa	
	75	22.2	20	Africa	
Palladius *de R R* 3.18	15	4.44	500	Italy	
	20	5.9	285	Italy	
	25	7.4	180	Italy	
	45	13.3	56	Italy	Yes
Mean for late Rep/early Imp Italy	27	8	157		
Mean for intercultivation in Italy	52.5	15.6	44		

We cannot know whether or not these figures reflect accurately the practice of oleoculture in the Roman period, but the figures do compare favourably with current practice in certain areas. For example, Delano Smith noted the similarity between Columella's suggested figures (Table 6.4) and contemporary practice in the Tavoliere of Foggia, where olives were intercultivated with wheat (Delano Smith 1979: 213). Modern sources show that olive cultivation varies greatly across the Mediterranean, although average figures for the whole country demonstrate an average of 84 trees per hectare (Mattingly 1994: 94-95). Fortunately for this study, the *Consorzio provinciale per l'Olivicoltura di Rieti* (1938; in Mattingly 1994: 94-95) provided figures specifically for the Sabina (see Table 6.5). These tree-spacing figures may be used for determining a range of potential yields for the study area, as well as for investigating possible intercultivation strategies (see Section 6.1.4). Mattingly is keen to emphasise the problems of determining an 'average' yield for olive production (1994: 97). The biennial harvest means that any statistics have to be averaged over two years to give a more accurate idea of production, but still I have attempted to use ranges of production rather than a strict 'average' yield.

Table 6.5 Olive statistics for the Sabina (after Mattingly 1994: 94-95)

	No. of trees	Hectares cultivated	Tree spacing	Density range (trees/ha)	Trees per hectare
Monocultivated	1,008,997	10,607	10 m	87-120	95
Intercultivated	226,279	10,403	21 m	16-47	22
Both	1, 235,276	21,010	-	-	58

Ancient sources for olive yields are extremely rare. Pliny (*NH* 17.19.93) mentions exceptionally yielding trees from Africa known as *milliariae* (or 'thousand-pounders') although this is almost certainly an exaggeration. Frank gives a production figure of 15-20 lbs[1] per tree for Italy, although he gives no indication of how he has arrived at this figure (Frank 1933: 171). Frank's figure was used by White (1970a: 391), although this was adjusted to take account of the alternate bearing, reducing the production per tree, somewhat arbitrarily, to 10-15lbs. A very low figure of three Roman pounds per tree was suggested by Dumont (1957: 243, 246), based on two modern Italian figures, but this yield is problematic due to the possibility of intercultivation.

[1] We must assume he means Roman pounds. 1 Roman pound = approximately 0.3275kg, whilst 1 Avoirdupois pound = 0.4536kg. The range of production would therefore be 4.9-6.5kg/tree using Roman pounds, compared to 6.8-9.1kgs/tree for Avoirdupois.

Any 'per-tree' figures may then be used in conjunction with the tree-spacing (Table 6.5) to translate this into kilograms potentially produced per hectare for comparison with modern figures. Modern statistics for Italy from 1961-2005 show that yields range from a minimum of 805kg/ha up to highs of 3,884kg/ha (see Table 6.6 and Figure 6.2), no doubt reflecting the alternate bearing, with a mean production of 2,265kg/ha (FAOSTAT data 2006a).

Table 6.6 Some posited annual yields for olive trees in the Mediterranean

Source	Location	Date	Yield per tree in kg	Trees per hectare	kg per hectare min	kg per hectare max	Notes
Frank 1933: 171	Italy	Antiquity	4.9-6.5	120-180*	588	1170	15-20 Roman lbs per year
White 1970a	Italy	Antiquity	3.3-4.9	120-180*	396	882	10-15 Roman lbs per year
Dumont	Italy	Antiquity	0.98	120-180*	118	372	3 Roman pounds per tree
Omodei Zorini 2001	Tuscany	Modern	6-7	200-250**	1200	1750	6/7 kg of olives per tree
Mattingly 1994: 94	Italy		14.8	(79)	1165	-	Antolini 1986, 164
FAOStat	Italy	1961-2005	9-11*	200-250**	805	3884	Average is 2265
(Sansoucy *et al.* 1983: table 1)	Italy	1983	17.5	133			
(Osborne 1987: 45)	Greece	Antiquity	6-7.5	100	600	750	Bad year 150 kg of oil
(Osborne 1987: 45)	Greece	Antiquity	16-20	100	1600	2000	Good year 400kg of oil
(Osborne 1987: 45)	Greece	Antiquity	11-13.75	100	1100	1375	Annual average 275 kg of oil
(Boardman 1976: 189)	Greece	Modern	10	-	-	-	Young tree
(Boardman 1976: 189)	Greece	Modern	50	-	-	-	Well established (>40 years)

* Cato's oliveyard (de Agr. 6) had 6,000 trees per 200 *iugera* (120 trees/ha) according to White (1970a: 391), and the range of Late Republican-Early Imperial trees/ha was from 120-180
**The 'traditional' spacing of trees in Italy is 200-250 per hectare (Omodei Zorini 2001)

Comparative evidence for olive production in Greece led Osborne (1987: 45) to assume a biennial production of 550kgs of oil per hectare (400kg in the good year and 150kg in the bad) for ancient Greece. He assumed 100 trees were planted per hectare, which meant a yield per tree of 1.5-4kg. Of course, as he is measuring the weight of oil rather than olives, we must adjust to take account of the extraction. Osborne does not provide his source for this and so we cannot know how much fruit was harvested to produce this oil. To deduce this is therefore a complex process as olive varieties differ in size and fruit to oil ratio.

One example, however, according to Forbes and Foxhall (1978: 38) is that 1 kilogram of oil may be extracted from 4-7kg of olives on Methana, Greece (14-25% extraction rate). This simple calculation would mean that Osborne's trees were producing between 6-28kgs of fruit. Work by Cresswell (1965; in Mattingly 1988b: 182) showed that ancient presses were capable of producing 20-25 kgs of oil per 100kg of olives (20-25% rate). This would translate to 1 kg oil from 4-5kgs of olives, narrowing the range from 6-20kgs olives per tree. Figures from antiquity are rare, but Pliny states that "*according to the ordinary computation, a* modius *of olives yields no more than six pounds of oil*" (*NH* 15.4.14). This equates to 8.75 litres, or approximately 7.84kg of olives, yielding 1.96kg of oil (Mattingly 1988b: 184), or 1kg of oil from 4kgs of olives (25% rate). Although shown here for comparison, we can only use the Greek figures for probable minimum production due to the noted differences in regional olive production, with Greece producing lower yields than Italy (Mattingly 1994: 98, tab. 3).

Figure 6.2 shows the ranges of yields from the Italian evidence. This demonstrates that there is some overlap between the posited yields of Frank and White, and 20th century production. Overall, the full range of olive yields given by the ancient and comparative evidence for Italy in Table 6.6 is from 396-3,884kg/ha. However, most of the data clusters between 588-1,750 kg/ha. Given the higher yields possible nowadays due to chemical fertilizers and improved pest control, the extremely high yield of 3,884kg/ha was likely to have been improbable for Roman period Sabina. It is likely that yields will have increased since the Roman period, not only due to technical improvements, but also because more mature trees produce better crops. We can therefore use the clustered data to determine potential olive yields in further analysis.

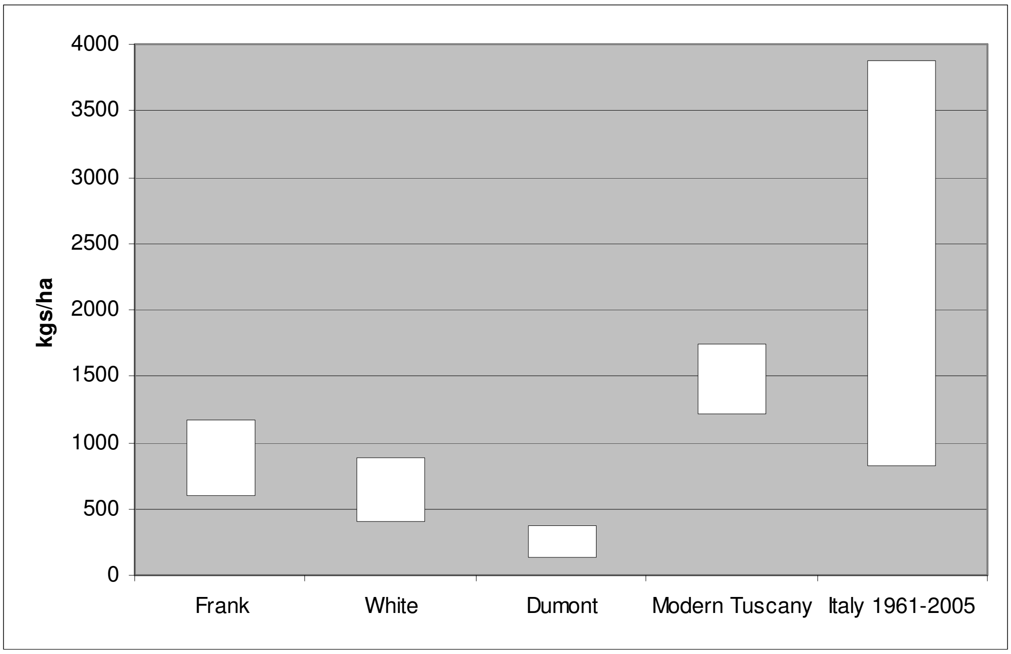


Figure 6.2 Ranges of yields for Italy from historical studies and modern yields

6.1.3 Vines

Yield data for vine cultivation is, particularly from the Roman period, more abundant than that for olives, yet is still not without its problems. Ancient sources seem to have gauged wine yields based on vineyards of one *iugerum*, and yields are highly variable (Table 6.7).

There is more comparative evidence available for vine yields than for olives, but Tchernia (1986: 360) has argued that using early modern Italian yields for determining Roman wine production is a useless exercise. This was due to the practice of *agricoltura promiscua* or intercropping (growing vines, olive oil, and wheat in alternating rows, see Section 6.1.4). I disagree with this argument, as these are still potentially useful figures. What must be done, however, is to factor in the reduction in yield to account for this as far as is possible.

Table 6.7 Ancient and archaeological sources for vine yields

Source	Ancient yield Area (in iugera)	 Liquid volume	Modern yield equivalent Area (in ha)	 Amount (litres)	 Litres/ha	Notes
Cato *Origines* (quoted in Columella *Rust.* 3.3.2 and Varro *Rust.* 1.2.7)	1	15 *cullei* / 600 *urnae*	0.25	7,860	31,440	
Jashemski 1979: 226	1	8 *cullei*	0.25	5,240	20,960	Not uncommon in Pompeii region today
Columella *Rust.* 3.3.3	800 grafted stocks	7 *cullei*	-	4,192	16,768	Seneca's yields and area around
Columella *Rust.* 3.3.3	1	7 *cullei*	0.25	3,668	14,672	
Pliny *NH* 14.4.42 (and quoted Cato)	1	100 *amphorae*	0.25	3,668	14,672	Seneca's yields
Columella *Rust.* 3.3.3	1	3 *cullei*	0.25	2,620	10,480	First class vineyards
Columella *Rust.* 3.3.11	1	20 *amphorae*	0.25	1,572	6,288	If yield is less, the vineyard should be uprooted
Columella *Rust.* 3.3.7	1	1 *culleus*	0.25	524	2,096	Lowest estimate of Graecinus
Columella *Rust.* 3.3.10	1	1 *culleus*	0.25	524	2,096	The very worst vineyards

Yields quoted by Duncan Jones (1982: 376) for early 20th century Calabria showed wine yields to be extremely low, between 0.82-1.3 *cullei* per *iugerum*, lower even than "*the very worst of vineyards*" (above), and Jongman used the figure of 2,000 litres/ha in his model of Roman agriculture (Jongman 1988: 132). However Jashemski (1979: 226), in her study of Pompeii, noted that yields of 10 *cullei* per *iugerum* (20,960 litres/ha) were not uncommon in the modern period and used this figure for the urban vineyard discovered.

Modern yields are problematic to use for comparison, as we only have overall yields for grapes rather than wine production derived from the FAO (FAOSTAT data 2006b). This means that standard extraction rates for grape weight to wine in litres must be used. This also does not take into account production of table grapes. There is no standard extraction rate, however, with figures encountered ranging from 0.59 litres of wine per kg of grapes in South Africa (Hough 2004) and the standard for Canada claimed as between 0.75-1 litre/kg (The Mackenzie Institute 1997). There are obvious shortcomings in using these figures, but comparable data from Italy was not available. Pearson (1997: 19) used the minimum figure of 0.83 litres/kg for medieval wine production, and this falls within the range cited above. By using the extraction rate of between 0.59-1 litre of wine per kilogram of grapes, the modern data was shown to have comparable yields to those from the Roman period (see Appendix V, Table V.2). A summary of results is below (Table 6.8 and Figure 6.3).

Table 6.8 Summary of Italian grape production compared with Roman yields, in litres per hectare

Date	Min	Max	Mean
FAO 1961	2,952	5,008	3,980
FAO 2005	6,823	11,573	9,198
Roman yields	2,096	31,440	-

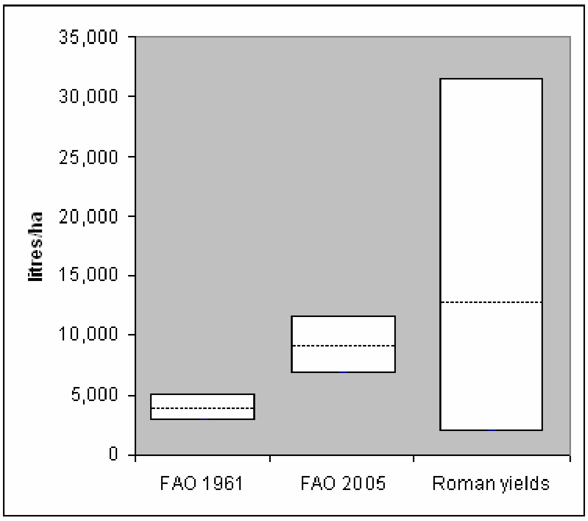


Figure 6.3 Ranges of yields for modern production compared to Roman yields (dotted line shows mean)

As can be seen in the table and figure above, the Roman figures actually far exceed modern production in some literary references. This may be explained by a variety of reasons. Firstly extraction rates may not have been the same. Factors such as the watering-down of wines and other additives is likely to have made a difference to the litres produced per hectare, but only if this happened at source rather than by consumers. The higher Roman figures are also most likely referring to exceptionally productive areas (in this instance Faventia and the Ager Gallicus) and it may be that modern countrywide averages are obscuring the differences in local production.

For further analysis, the yields of Seneca (16,768 litres/ha) are used as the maximum production figure for monoculture of vines in the study area, as this yield was looked upon by Columella (*Rust*. 3.3.3) as being particularly high for the area. The minimum yields to be used were those from "*the very worst of vineyards*" (Columella *Rust*. 3.3.10) at 2,096 litres per hectare, as this is a general statement about low production.

6.1.4 Intercultivation

The intercultivation of crops, particularly olives and wheat, or olives and vines, is common in Central Italy and, as stated previously, it has been suggested that this is due to the topographic unsuitability of the region to large-scale monoculture (Potter 1979: 125; Barker 1985: 82). These differences – what Garnsey calls "*spatial diversification*" (1988: 49) – is advantageous to the farmer as it means he has access to a number of different microclimates. Also, crops do not ripen simultaneously when sown in different environments, and so this offset works to the farmers' advantage as it can spread the workload. Implications for the model are that crops are not likely to be cultivated in large contiguous areas. Instead, they are likely to be mixed with other field crops and tailored to the resources of particular areas.

Crop diversification is a common feature of small farming, and the Mediterranean farmer has traditionally practised forms of mixed farming. This includes a mixture of different crops, or crops with livestock (Garnsey 1988: 49). This strategy is particularly useful as it protects against failure of entire crops through plant diseases, drought and so on, due to the different requirements and growth cycles of each crop (Sullivan 2003). In the Mediterranean, peasants cultivate wheat, barley, legumes, vines, olives and fruits in combination (Gallant 1991: 36-37). The cultivation of legumes within a rotation not only provides nutrients for the soil, but both humans and animals may eat the produce. Legumes were considered "*poor man's food*" and were not generally consumed by the wealthier classes (Brothwell 1988: 249). Nevertheless, legumes are very nutritious and could be consumed in times of shortage.

Intercropping (or intercultivation, polyculture) is common in the study area. From the digital land use map of the study area it can be seen that a large percentage of land is currently used for what has been termed 'complex' agriculture (see Figure 1.7, page 17). This was described as being a mixture of annual and permanent arboriculture intercropped with arable, and areas with mixed arable and vegetation. From the cadastral map of Nepi (Chapter 4), this picture was further elaborated with each plot of land described as containing activities such as the intercropping of arable, vines and olives; arable, vines and fruit; arable and vines; and arable and olives. Therefore, we may imagine that any combination of these crops is possible.

Three types of intercropping are all outlined by Sullivan (2003; see also Gallant 1991: 38-40). These are mixed intercropping, row intercropping, strip intercropping, and relay intercropping. Mixed cultivation refers to the cultivation of two crops together with no specific spacing or distribution. Row intercropping refers to a similar method, but cultivated in rows. This is the type most likely to occur in our area as it is used especially with vines or olive trees, as shown by the 19th century cadastral evidence. Strip intercropping is not relevant to this study as it involves the spacing being wide enough to allow machinery. Relay cropping is the successive cultivation of crops in the same year, planting the second crop before the harvesting of the first crop.

The Roman texts refer to mixed cultivation or row intercropping, with grain crops sown between olive trees (Columella *Rust*. 5.9.7; 2.2.24). White argues, based on the sources and modern practice, that grain was more likely to be sown between olive trees than rows of vines (1970a: 124). An alternative method, known as *vitis arbustiva*, was to train vines using trees such as the poplar, elm or ash (Columella *Rust*. 3.3.2; Varro *de Arb.* 16).

Disadvantages of intercultivation techniques include the increased labour and crop management required, the need for careful selection of crops so as not to compete with each other, and the quite substantial reduction in yield for each crop (see below). Indeed, it has been argued that Columella's low yield of 4:1 for wheat in Italy is due to the wheat being intercropped with vines (White 1970a: 49). Advantages, as shown by modern intercropping are, however, the greater overall yields per hectare (*c*.10-20% higher) despite individual low crop yields, better weed control, greater fertility (if cultivated with legumes), and a lower likelihood of all the crops failing concurrently (Sullivan 2003; Gallant 1991: 39-40; Osborne

1987). Further, this practice effectively extends the growing season as it raises the temperature of the ground by several degrees. The practice also demonstrates minimal competition occurring between plants as roots are at different depths, and finally trees could provide shade and vines may help prevent superficial erosion of the soil (Barker 1985: 60).

As stated above, individual yields of plants are likely to be much lower if intercropped. White uses this fact to argue that yields of wheat would naturally be halved (White 1970a: 49), and it seems sensible to use Columella's low yield of 4:1 for wheat, given the theory that it refers to intercultivated grain (Section 6.1.1). However, the potential yield of the remaining crops must also be quantified. The two economies to be approached here are 'olives and wheat' and 'vines and wheat'.

The spacing of trees is paramount in such calculations. In Table 6.5 above, it can be seen that there were far fewer trees per hectare than in monoculture of olives. Density ranged from 30-56 trees per hectare according to the agronomists, with the range from 30-47 in the early Imperial period (see Table 6.4, page 255) and explicit figures for the Sabine region give a range of 16-47 trees per hectare (Table 6.5, page 256). These tree spacings are highly comparable, with the same maximum tree density in modern Sabina and in Columella (Table 6.9).

Table 6.9 Comparison of intercropped olive yields (after Tables 6.4 and 6.5)

	Trees / ha	Olives kg / tree	Kgs olives
Columella	30-47	3.3-14.8	99-696
	30-47	4.9-7	147-329
Modern Sabina	16-47	3.3-14.8	53-696
	16-47	4.9-7	78-329

Table 6.9 demonstrates that some modern orchards were sparsely planted in comparison, particularly as the mean density was only 22 trees/ha compared to the Roman mean density of 44 (Table 6.5). However, this analysis has the express intention of testing the Roman evidence for production and the implications of these texts, and therefore the Roman range is used in further analysis. This, of course, is added to the wheat yield of 4:1.

Intercropping vines with wheat is more difficult to assess, as there are no explicit ancient figures for intercropped wine yields. The production figures noted in Section 6.1.3 from the ancient sources range from 2,069-16,768 litres/ha, and we can only assume that the lower yields were more likely. The lower yields of this range (2,069-10,480 litres/ha) were therefore used as the wine yields for intercropped vines. Again, this is in addition to the wheat yield of 4:1.

6.2 Methods of agricultural practice

Before attempting any reconstruction of land use, it is necessary to highlight the diversity that occurred within farming strategies. Farming did not merely range from peasant smallholdings to rich villas, but also incorporated a range of different activities at different scales. A major way farming practice differed was in its many ways of increasing productivity.

It has been argued that pre-industrial economies had strict limits on the extent to which productivity may be increased. This obviously would impact on the level of surplus available to non-agriculturally productive populations (Morley 1996: 4). Technological improvement such as mechanisation and the introduction of chemical fertiliser has increased productivity enormously in recent years. This type of development, however, was mostly absent from antiquity. This meant that techniques of increasing productivity in the ancient period relied on factors such as a change of economy, intensification of land use, improved technology, the increase of the labour supply or longer man-hours, expansion of the area cultivated, crop rotations with legumes, and so on.

Changing the economy, for example from crop cultivation to a pastoral economy, can improve returns, particularly in areas of low soil fertility. Animal rearing can be argued to have a higher return than field crops (Varro *Rust*. 2.4), although this must surely depend on the environment of the area and which crops were cultivated. However, there are limitations in herd size as, if not driven to winter pastures, the animals would need to be kept in stalls during the winter period, and would require large quantities of fodder (Varro *Rust.* 2.4-2.5; Columella *Rust.* 6.3.1-8).

Intensification of land use would increase yields as more seed is sown in the same acreage, though continual cropping will inevitably lead to soil exhaustion without some form of fallow or rotation. An increase of labour supply would mean an increase in production, usually due to factors such as extra weeding and ploughing which will improve the quality and quantity of the crop, as roots are not competing. Expansion of the area cultivated can obviously provide a higher return due to the larger area being farmed.

However, most of these techniques are merely temporary changes that would not necessarily mean long-term increase in product. To sustain an agricultural increase one needs to improve the quality and not just the quantity of these factors (Jongman 1988: 27). The only factor where this is not the case is in the expansion of area cultivated, assuming the land is farmed at the same intensity.

As chemical fertilizers were not used widely until the early to mid-twentieth century, other forms of soil improvement were necessary to increase fertility, or indeed maintain its fertility if it was heavily worked in antiquity. The application of manure (both animal and green) and litter was one of the most common ways of achieving this. Manure was mostly supplied by stall-fed animals and birds (though human waste could also be used, Columella *Rust*. 2.14.1) and applied before sowing in September. As such, manure was often scarce, and much would be unavailable for agricultural use during the year due to the practice of transhumance, or pasturing in meadows. Small farmers especially would not necessarily have had enough resources to support draught animals on their plots. Any available, however, could be supplemented by organic waste such as wood ash, olive skins, or olive-lees (*amurca*) (Cato *de Agr.* 93; White 1970a: 127-129, 141). The by-products of olive production are still used today as animal feed (Sansoucy *et al.* 1983)

Those without the resources to obtain animal manure from elsewhere often used an alternative form. 'Green manuring' involved the direct ploughing-in of a specially-grown grass (vetch, rye grass *et cetera*) or a leguminous crop (lupines, sweet clover, broad bean, and so on) in order to restore nitrogen to the soil (White 1970a: 135-136). Nitrogen has long been identified as a major contributor to soil fertility, and experiments from the late 19th and early 20th century (Hall 1905: 35; in Shiel 1991: 51-52) showed the beneficial effect of nitrogen on wheat yields in Britain. This practice does, however, deny the landholder the extra produce from the crop. If sown in rotation, however, this practice would greatly benefit subsequent yields, as demonstrated in the wheat yields sown after legumes in Table 6.3 (page 253).

6.2.1 Fallowing and crop rotation practices.

Other agricultural practices which impact heavily on the crop production of an area are fallowing and rotations. These aid the fertility of the soil, guarding against soil exhaustion, and can dramatically affect the amount of crop grown on a landholding. In order to incorporate these into the model it is therefore necessary to outline the variety of techniques used in the Roman period. Though discussed briefly above, these are assessed here in more detail in order to determine their potential impact on the yield models produced in subsequent chapters.

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. In order to keep the agriculture sustainable, it is therefore necessary to carry out fallowing or crop rotation. It has been argued that three-course crop rotation was not introduced until the medieval period, and that Roman farming techniques were essentially 'primitive' (Parain 1966; Jones 1974: 18). However, there was great diversity in the methods practised for the maintenance of soil fertility, and no common system seems to have been followed (Spurr 1986a: 117-125; White 1970a: chap. 4; 1970b). The various systems are described below, but the reasons for choosing which of these types of system rested on a number of factors. These included the amount of labour available, the amount of land owned, the location of the agricultural units, whether livestock was kept, and, if a tenant or slave, if the landlord allowed it (Gallant 1991: 53). Gallant's study is not explicitly devoted to Roman agriculture, but peasant farming as a whole, and so certain factors will be universal.

Some very rich soils were considered strong enough for successive cereal cropping. Varro (*Rust* 1.44.2-5) states that,

> *…in rich soils, such as those of Etruria, you can see productive cornfields which are cropped every year.*

Although this may have been the case in some parts of Etruria, it cannot have happened a lot here due to the variability in soil quality and the likelihood of soil exhaustion. Simple fallowing involves merely the resting of the soil in alternate years, and was considered to be good practice in the Roman period. Benefits were that fallowing helped with weed control and allowed the accumulation of nitrogen (Shiel 1991: 76). Often on more intensive farms, this land would have been used for winter pasture (Section 6.3), and the relationship between animal rearing and crop cultivation has often been thought to have been a productive one, particularly as the animals would provide vital manure if pastured in these areas (Spurr 1986a: 27; White 1988: 222). However, more complex fallowing schemes including fodder crops are thought to only be applicable on larger estates, rather than small farms (Spurr 1986b: 171)

This fallowing system has great implications for the productivity of the area as it effectively halves the amount of wheat that could be produced per year. However, if the fields were used as pasture during the fallow, it would have increased the fertility of the resting soil due to the direct application of manure. This practice did occur in the Roman period according to the agronomists (Cato *de Agr.* 30; Varro *Rust*. 2.2.12), but was not considered strictly necessary if the soil was very rich (see above). Given the potential yield ratios of the study area, it was probably possible to fallow and still support a reasonable number of people (see Chapters 7 and 8).

Although complete rotations of the type known from later periods were not practised, several different rotation schemes are known from the ancient writers (see especially Pliny *NH* 18.91, and Columella *Rust* 2.17.4). Virgil states that, "*by rotation of crops you lighten your labour*" (*Georg*. 1.79) and that one should, "*put down to yellow spelt* [a] *field where before you raised the bean with its rattling pods*" (*Georg*. 1.73-4). These have all been discussed in detail in various works (Spurr 1986a: 117-119; White 1970a: 121-123) and so will not be discussed here. It is sufficient to say that there existed much diversity in the practise of fallowing and rotations that impacted considerably on the amount of wheat yielded.

As with fallowing, rotations can (depending on the type practiced) essentially halve the amount of cereals produced, but instead produce a year's worth of a different crop, with different uses. Not only do legumes restore nitrogen to the soil, they were also used for human and animal food. However, given the serious shortage of animal manure, it was often the case that, as mentioned above, these crops (such as lupines, vetch and field beans) were ploughed in rather than harvested as "green manure", thereby providing no extra source of food (White 1970a: 190).

The fallow and rotation systems mentioned in the ancient literature range from a simple two-field fallow to three field rotations involving legumes or other field crops (see Pliny *NH* 18.91). The models used in further analysis are therefore as follows, the last two systems being my own derivation to take into account rotations where the crop was either consumed or ploughed under as green manure:

- Continual cropping
- Two-field fallow
- One-quarter fallow and three-quarters cropped
- Three-quarters fallow and one-quarter cropped

6.2.2 Variety of production

As mentioned above, not all rural sites were dedicated to arable agriculture. Some had a predominantly pastoral economy, whilst others were dedicated to cash crops. Some other rural sites, for example high status villas, may not have had a productive function. Many villas were seen as the country retreats of the elite, and as such did not have an explicit productive function, though they were unlikely to have none (Purcell 1995: 162-163). Others may have been dedicated to other types of production with no need for expansive grounds. The tradition of *pastio villatica*, for example, was said to have been practised, not only in the suburbs of Rome, but also around other market centres. *Pastio villatica* was a productive system geared towards the market, which was essentially divided into three categories. These were the breeding of birds, hares and fish, although other specialist activities included beekeeping, dormice, and game reserves (Varro *Rust*. Bk. 3). Morley (1996: 93) argues for the intensive practice of *pastio villatica* in the southern part of the study area (see Chapter 2.1.2). It was only in those areas with good transport access to an urban centre that it would have been profitable to follow such a market-oriented regime. Even lower status farmers in these areas would have found it profitable to intensify production to some level (see Simylus, Chapter 2).

Although far removed from the subsistence-style arable farming probably prevalent in much of this area, we do have some limited evidence for such activities. There are only a few literary references within the study area, which are to beekeeping near Falerii Novi (Varro *Rust.* 13.16.10-11) and the rearing of fieldfares (a type of thrush) in the Sabine country (Varro *Rust.* 3.2.15, 3.4.2). Archaeologically we have little physical evidence. The villa of Settefinestre contained evidence for the consumption of fifteen different bird species, discovered as food debris from the late 1st century AD levels (King *et al.* 1985). However, surface survey in South Etruria has recently brought to light what is thought to be a fragment of a *glirarium*, a vessel for the fattening of dormice (di Giuseppe, pers. comm.).

Across the river in Sabina, excavations of a suburban villa at the site of Forum Novum uncovered some interesting features. The villa, first discovered through geophysical survey, contained a large central fishpond, floored in *opus Spicatum*. Inserted into the walls were a number of pottery vessels. This layout is thought to have been for the breeding of eels, common in the Roman period (Gaffney *et al.* 2001). Another fishpond had previously been excavated at the site of Monte Gelato, and this had also been interpreted as for the breeding of eels (Cartwright 1997: 404).

Fish-breeding is argued to be a prestige activity, for which there is little profit but great aesthetic value. Varro (*Rust*. 3.17.2) states:

> *For in the first place they are built at great cost, in the second place they are stocked at great cost, and in the third place they are kept up at great cost.*

However, this primarily relates to the great seaside fishponds of the 1st century BC, which were linked to sumptuous and extravagant display. As well as involving the conspicuous consumption of water, they also represented control over a scarce and valuable resource. Fish themselves are argued to have been scarce in this period due to the relatively young age of the Mediterranean and over-fishing (Higginbotham 1997: 55-57). The Early Imperial period, however, saw the imitation on a smaller-scale by inland villas, such as that at Forum Novum, which required less cost and could be a direct source of high status food (Higginbotham 1997: 61, 67).

These discoveries (the *glirarium* and fishponds) in the study area demonstrate that these sorts of activities did indeed occur in these regions, and there may therefore be many more undiscovered examples from other rural sites, given the literary evidence. Beyond the city's immediate hinterland, however, Morley argued that agricultural holdings would have grown a mixture of cereals, vines and olives. Intercultivation (as discussed in Section 6.1.4) was considered the normal strategy for both large and small farmers. It was seen, not only as a risk avoidance strategy to guard against poor harvests, but also to cultivate the most appropriate crops for the soils available (Morley 1996: 108, 118). Combinations and proportions of crops grown could therefore have been variable, and dependent on the natural resources of the area. Self-sufficiency was seen by the agronomists as desirable for estates (e.g. Cato *de Agr*. 2.5-7). Complete self-sufficiency, however, was not often feasible, and so some trading of goods was likely to have been necessary for certain commodities (Garnsey 1999: 23-24), but in general it is thought that most agricultural units would have produced a variety of crops and other products as a risk buffering strategy amongst other factors (see below).

6.2.3 Bad year economic strategies

As we can see from the results in Chapter 3, the majority of potential territories in the study area fall into what we could call the category of small 'peasant' farms. Much work has been done on the economic viability of such plots and risk avoidance strategies. Those cited here do not exclusively discuss Roman farming, but include other forms of Mediterranean strategies, both ancient and modern. However, there are common themes that are universal in such economies. How intensively these small plots were farmed, and what was cultivated, has important implications for our model as they affect yields, and therefore carrying capacities.

It has been argued that food shortages were common in antiquity, and that the majority of the population were likely to have suffered from endemic under-nourishment or chronic malnutrition. The fear of food crisis is clear from direct and indirect references in the ancient sources, but widespread malnutrition is difficult to prove in the archaeological record without substantial evidence from skeletal populations (Garnsey 1999: 2-3).

Food shortages occur for many reasons, for example, an imbalance between the resident population and available resources, climatic factors such as drought or flooding, other natural causes such as plant disease or insect infestation, or social and political factors such as warfare, and possible associated profiteering. The most serious crises occurred when harvests failed successively, or wars were of long duration, or the combination of bad harvests with epidemic disease. This could be exacerbated by the lack of an efficient distribution system supplying areas with a deficit from those with a surplus (Garnsey 1988: 271; 1999: 5; Jongman and Dekker 1989: 114-116; Halstead and O'Shea 1989: 3).

It has been maintained that, whilst small-scale shortages were common, rural populations were generally able to avoid more serious famines (Garnsey 1999: 23, 35; 1988: 53-54). It was instead urban populations that were particularly vulnerable as non-producers and, though public intervention has been argued to be the norm rather than the exception in the Roman world (Jongman and Dekker 1989: 118), they could not always rely on public distributions in times of famine. These arguments primarily relate to Rome, and so we might imagine that smaller local centres could have been more at risk than the capital, given that it was politically prudent to prevent food riots in the seat of power using grain distributions wherever possible. The feeding of urban centres will be approached more thoroughly in Chapter 8.

The impact of shortage is determined by a number of factors: how often shortages occur and how long they last, and how much of a landscape is affected (for example bad weather affecting only part of a cultivated area). Responses include mobility, diversification, use of emergency foods, fragmentation of landholdings, storage and exchange (Halstead and O'Shea 1989: 3-4).

Generally, small farmers will not attempt to maximise their average return on a crop. This may seem surprising, but in fact is economically safer, as it involves little or no risk to the end result. It is better to receive low returns than none, and as such, crop diversification, intercropping, and fragmentation of landholding are common in Italy as well as Greece (Gallant 1991: 36ff). Fragmentation of landholding has been briefly touched upon in Chapter 3 as one strategy adopted by Roman landholders. It is still the case today within the agriculture of modern Italy, and has been described by Garnsey (1988: 49) as "*an eternal feature of Mediterranean farming*". The remaining two strategies – crop diversification and intercultivation – have been discussed in-depth in Section 6.1.4. Alongside this, small farmers are argued to have always utilised uncultivated land for foraging (Garnsey 1988: 53; also briefly discussed in Section 3.3) and so would have been able to supplement their diet in this way (see Frayn 1979: 57-72 for a detailed discussion of forage foods; see also O'Shea 1989).

One of the most important aspects of risk avoidance is storage of surplus and consequently the number of people supported in an area (Gallant 1991: 5-6; Garnsey 1988: 20-21). This is an important factor taken into account in the models of Chapter 8. The percentage of the crop that farmers stored annually impacts on the available food supply of any given year, and consequently on how much is available to non-agriculturally-productive populations. The success of the harvest was paramount and, if this failed, a sufficient storage was required to counteract the shortfall. Storage was considered an "*economic necessity*" for a peasant. The storage of food was necessary to provide a constant food supply throughout the year, particularly during periods of unproductivity, and storage facilities are regularly unearthed at archaeological sites (Garnsey 1988: 53; Forbes and Foxhall 1995: 69; O'Shea 1989: 58). Comparative evidence from later societies implies that peasants probably aimed at having anything from a year to a year and a half's supply of food in storage, to guard against bad harvests and shortages (Gallant 1991: 96). Looking to Greece again, Forbes noted that two years' worth of wheat and four of olive oil was considered the minimum (Forbes 1989: 93).

In the sources we have little direct information regarding suggested storage amounts. Cato (*de Agr.* 3.2) advises that a farmer should have plentiful storage, but this is for taking advantage of market prices rather than as a strategy for avoiding food shortage. He lists the equipment needed for storage for both a 240 *iugera* oliveyard (*de Agr.* 10) and a 100 *iugera* vineyard (*de Agr.* 11), but we cannot know how many years' worth of production this was intended to store.

Archaeological evidence ranges from huge state-controlled granaries supplying the military and large towns, down to small household vessels. One must have adequate storage facilities, however, to avoid the crop being lost through pestilence, rotting through the presence of excess moisture, or other such problems (Garnsey 1998: 236). Ethnographic parallels from the Mediterranean and Africa have been used to show that losses could be up to 30% (Forbes and Foxhall 1995: 73), whilst other studies have argued for higher typical losses of up to 50-80%, depending on the effectiveness of the storage facilities (Gallant 1991: 97). Losses can be huge, as shown at a site in Roman Britain where there were recovered high concentrations of fauna such as granary weevils that thrive in conditions with significant amounts of mouldy and decaying grain (Smith and Tetlow 2003). Forbes and Foxhall blame such significant losses on the change from traditional systems (e.g. the imposition of Mediterranean storage techniques into Britain, a completely different and unsuitable environment), and so consider these high loss figures excessive. This is usually because the crops stored are less resistant to unfamiliar pests, and the modern storage methods adopted inadequate. Traditional, well-established methods such as those used in antiquity are therefore thought to have resulted in losses lower than 30% (Forbes and Foxhall 1995: 73-74).

Long-term strategies for avoiding food shortages involved demographic changes, and are of less consequence to this model. Peasants could limit their families, and therefore the number of mouths to feed in a number of ways. These included getting married at later ages, extending the interval between births, using contraception or practising abortion, as well as infant exposure (Garnsey 1988: 272; Dyson 1992: 187-188). Comparative data from Greece showed that, during shortages in the Second World War, one emergency response was to marry off daughters (sometimes forcibly) to reduce the number of dependants (Forbes 1989: 95). This is an extreme form of dealing with food shortage, and generally farmers would have practised different cultivation strategies either instead of, or as well as, these extreme measures of population limitation (see below). State-wide systems for avoiding shortage included bringing more land under cultivation, expanding territory, exporting populations through colonisation, and importing food in exchange for goods or as tax (Garnsey 1988: 69).

It is generally agreed that the survival of the peasantry was dependant on the success of the production strategy followed, which is argued to have tended toward low-risk ventures (Garnsey 1988: 43). Their behaviour is fashioned by many factors, the most important of which were tenure system and farm size. Local climate and soil fertility, the crop cultivated or other land use, the technology and resources available also affected the system followed. Population factors also contributed, with family structure and general demographic conditions affecting intensity and extent of cultivation. The presence of a market and imposed burdens such as taxes or rents would also have played a role in economic decisions and agricultural strategies (Garnsey 1988: 45). The models approached in Chapter 8 attempt to take all of these factors into consideration when modelling food production.

6.3 The potential contribution of livestock

Roman animal husbandry is a difficult aspect to assess. Like arable farming, modern changes in technology have meant that statistics from modern meat and dairy production are very difficult to use to create models of ancient practice. This could potentially be a big problem when dealing with milk and meat yields due to changes in stature and productivity. Barker (1985: 28) cites factors such as improved housing, use of drugs, and improved feed as some of the contributing factors to such changes. Our main source of evidence for such a study must therefore come from analysis of excavated animal remains from Roman contexts.

Despite the relative lack of zooarchaeological assemblages from excavated contexts (MacKinnon 2001: 651), those we do have can tell us a lot about the nature of animal-rearing in the Roman period. Barker (1985: 19) identified six aspects that faunal analysis can contribute to the study of husbandry in his work on prehistoric farming. These are species identification, relative importance of species, age structure, size of animals, evidence for disease and other conditions, and aspects such as butchery and fragmentation patterns. For this analysis the most important factors are evidence for stature to gauge meat yields, age to determine what type of herd was being kept (i.e. for secondary products or meat), and the composition of animals at a site to establish the farming strategy. Any animal would also have required feeding and space to graze, and these aspects were also investigated.

Delano Smith (1979: 219) stated that animals would have been a common feature on Roman farms of all classes, and the most common of these would have been cattle, sheep, goats, and pigs. The dominance of these particular animals is attested by a number of excavations of various periods. Barker stated that they were the most common animal types in prehistoric European assemblages (1985: 20), as shown by the results of excavations at Narce (Chapter 2; Potter 1976), where the highest proportion of animal bones belonged to sheep and goats, followed by pigs then cattle. Roman period remains from another site in the area, Monte Gelato, indicated instead a dominance of pig breeding, although other species are present, including sheep, goat, ox, deer, hare, dormouse, chicken, thrush and eels (King 1997: 383-385, 398; West 1997: 403-404; Cartwright 1997: 404), and this supports MacKinnon's argument that pigs are the most frequently represented animal overall in excavated contexts of this period in central and northern Italy (MacKinnon 2001: 651, 656; see Chapter 5). Faunal evidence from Roman high-status villa estates in or near the study area also follows this pattern. Both Settefinestre (King *et al.* 1985) and the Villa dei Quintili near Rome (De Grossi Mazzorin 1987) show large proportions of pigs with lower number of sheep and goats, and very few cattle (Table 6.10 and Figure 6.4).

Table 6.10 Proportion of domestic animals at villa sites (after De Grossi Mazzorin 2004: 48, tab. 5; King 1997: 385, tab. 66)

Settlement	Date	Sample Size (NISP)	% cattle	% caprine	% pig
Settefinestre	1st C BC-1st C AD	175	10.8	42.3	46.8
Monte Gelato	Early Imperial	296*	6.8	21.6	71.6
Villa dei Quintili	1st-2nd C AD	132	-	13.6	86.4
Settefinestre	2nd C AD	1520	13	17.3	69.7
Settefinestre	2nd-3rd C AD	710	6	15.4	78.5

*Figures adjusted to exclude specimens of horse, dog and cat

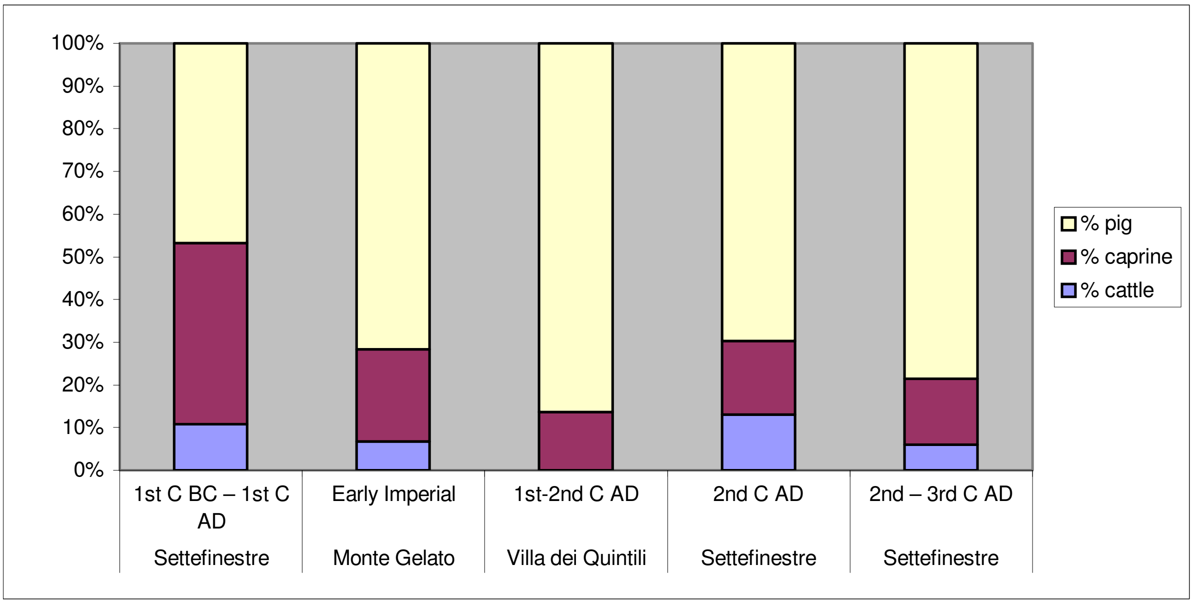


Figure 6.4 Proportions of animal remains at villa sites (from Table 6.10)

Delano Smith also outlines six different systems of farming, based on ethnographic evidence, in which animals mostly play a role (1979: 227-229, fig. 30). These are:

- Peasants with no livestock. A kitchen garden, 1-2 orchard trees, 1-2 pigs, maybe a goat. Livelihood mostly from fishing/mining or poor labourers
- Peasants with some land (polyculture), 1-2 pigs, a small flock (1/2 dozen sheep) and 1-2 goats.
- Rich peasants with modest amount of farmed land, a large flock/herd (50-100 sheep/cattle)
- Butcher's flock/herd (100 animals)
- Arable estate farm with domestic pigs, a few goats and sheep, cattle for ploughing (and horses and mules for transport)
- Pastoral estate farm with large numbers of sheep or cattle (100s-1000s)

According to these models, even the smallest agricultural unit would have kept animals, but determining their 'yield' is the most complex of calculations. Aspects such as the consumption of secondary products, the use of livestock for traction, and ultimately as a source of meat mean that determining the contribution of animals to the diet is nigh on impossible. However, we can gauge a basic range for each animal.

6.3.1 Pigs

As discussed in Chapter 5, pigs may eat scraps and refuse and, though bred only for meat, are considered very useful animals to keep within poor communities. However, there is not much information available regarding how many pigs were likely to have been kept per household. Varro (*Rust*. 2.4.22) suggests that a herd of 100 is a reasonable number, although they may go up to 150 or higher. This, however, refers to larger-scale breeding (White 1970a: 316). Smaller-scale pig rearing has also been discussed, but it is only from the models of Delano-Smith (above) that we may assess possible numbers on smaller farms.

Determining a 'meat yield' per animal is a difficult process. Figures given by Tennant (1885: 83; in Delano Smith 1979: 220) for 19th century Sardinia show that there are different ages at which pigs are slaughtered. These figures showed that a two-year old home-reared pig yielded 400lbs of meat (181kg) whilst a six-month old porker yielded between 30-35lbs of meat (14-16kg). Slicher Van Bath (1963: 334, Table IV) gave statistics showing that the deadweight of pigs in Schleswig-Holstein (16th century) and Denmark (17th century) was between 35-40kg (Table 6.11 for summary of this data). These figures, however, refer to meat yield rather than deadweight of pigs.

In the modern period, pork pigs reach their killing weight of 70kg within only twenty weeks, and bacon pigs reach 90kg within twenty-two weeks (Barker 1985: 34). Modern FAO statistics (FAOSTAT data 2006c) show that the average weight of a pig carcass between 1961-2005 in Italy was a little higher than this at 106kg (the range was 92.9-118.1kg) (Table 6.11).

Table 6.11 Comparison of weights of meat yields from pigs

Source	Date	Age	Weight in kg
Schleswig-Holstein	16th C	-	35-40
Denmark	17th C	-	35-40
Sardinia	19th C	2 years	181
Sardinia	19th C	6 months	14-16
Italy	1980s	5 months (20-22 weeks)	70-90
Italy	1961-2005	Unknown	92.9-118.1

Given the different feeding conditions in antiquity, i.e. scraps rather than factory-farmed with generally higher quality food, it has been argued that Roman pigs would have taken longer to reach an appropriate killing weight (Barker 1985: 35). This may also be inferred from comparison of the figures in Table 6.11. Roman evidence from faunal assemblages suggests that most pigs were slaughtered at the age of three years, and that males were killed preferentially (MacKinnon 1999: 119-125, 134-139; in MacKinnon 2001: 656). At Monte

Gelato 75% of the pigs from the Early Imperial contexts were slaughtered by the time they had reached two years, suggesting that nearly all would have been slaughtered by the age of three, leaving a small number of what were probably breeding sows to middle and old age (King 1997: 387-388).

Establishing the size of pigs at slaughter for the Roman period is a difficult matter. However, a study on medieval farms in the Carolingian period determined from anthropological and excavated skeletal evidence that a 60kg pig would have yielded 21.6kg of meat, 3.75kg of edible offal, and 14.4kg of fat (Pals 1987: 200-201). Table 6.12 shows the total calories that may be acquired from a pig of this size.

Table 6.12 Calorific 'yield' of a 60 kilogram pig in the Carolingian period (after Pals 1987: 120, tab. 7.1; FAO 2001: section III.3)

	Weight in kg	% of total deadweight	Calories per 100g	Total calories	Daily calories
Meat	21.6	36	326	70,416	192.9
Offal	3.75	6.25	113	4,237.5	11.6
Fat	14.4	24	712	102,528	280.9
Total	39.75	66.25	-	177,181.5	485.4

Assuming that a peasant had one pig of this stature slaughtered per year, then the total addition to the diet would be 485 calories per day – approximately a quarter to a fifth of the daily requirement (see Chapter 7). This, of course, was unlikely to feed just one person, and so it may be suggested that one pig could have contributed approximately 5% of the annual dietary intake for a family of five.

However, it has already been noted that pigs were slaughtered at the ages of two or three years according to the Roman faunal evidence in the study area. These pigs, though growing at a slower rate than modern pigs, would still have been heavier than the pig described in Table 6.12. Determining the weight of these older pigs is difficult. The withers height ranges of pigs found in excavated contexts are comparable to the modern *Sus scrofa* (Table 6.13 and Figure 6.5) yet modern pig weights are likely to be far higher.

Table 6.13 Comparison of withers height ranges for pigs

	Withers height range
Modern *Sus scrofa* (Dewey and Hruby 2002)	550-1100mm
Early Imperial Monte Gelato (King 1997: 390)	690-780mm
Settefinestre (King *et al.* 1985: figure 206)	570-930mm

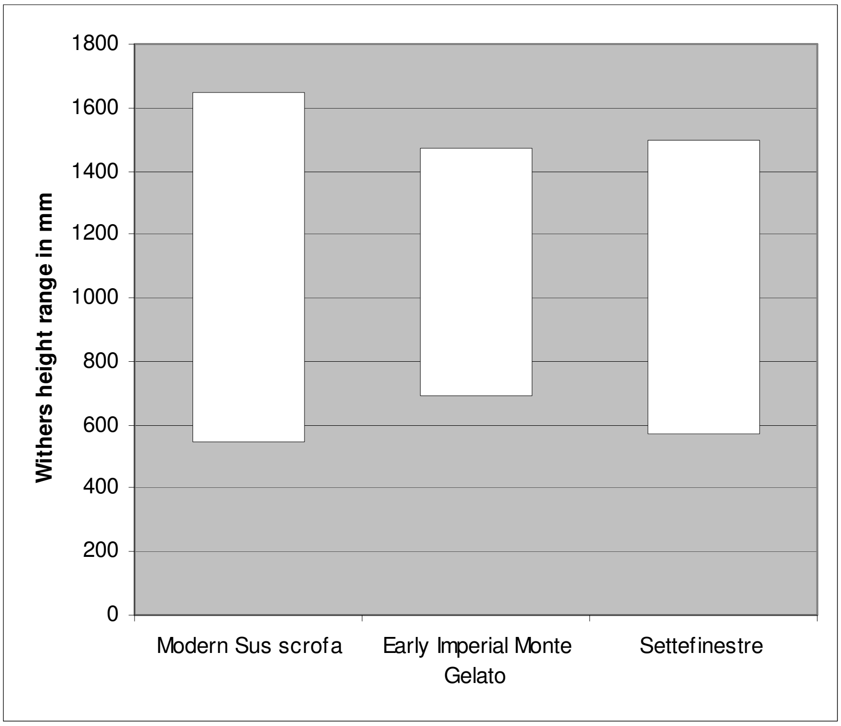


Figure 6.5 Comparison of withers height ranges for pigs (after Table 6.13)

Given that most pigs kept on a small farm were likely fed on scraps, their diet would not have been sufficient to fatten them on the scale of modern production. A comparative study in the Philippines measured the weight-for-age of pigs held by smallholders (Morea *et al.* 1999). Though not directly comparable in exact species or environment, these pigs were shown to have very poor weights for their age. The median weight in the two samples studied was 5.5 and 5.7kg/month of age. If we apply this to the Roman data it would mean that a three year old pig would have a weight of approximately 198-205kg. A two year old pig would have been 132-137kg. The medieval example, at 60kg, may therefore have been in the region of 10-11 months at slaughter. Given that these are minimum figures for weight, these may be used to determine the minimum edible yield from a two and three year old pig as a Roman model. The results from Table 6.12 were scaled up to the new deadweights (Table 6.14). This was considered appropriate as the FAO state that aspects such as the edible offal are generally a percentage of the deadweight (FAO 2001).

Table 6.14 Potential meat yields of Roman pigs

		Weight in kg	% of total deadweight	Calories per 100g	Total calories	Daily calories
2 year old	Meat	47.52	36	326	154915.20	424.43
	Offal	8.25	6.25	113	9322.50	25.54
	Fat	31.68	24	712	225561.60	617.98
	Total	87.45	66.25	-	389799.30	1067.94
3 year old	Meat	71.28	36	326	232372.80	636.64
	Offal	12.38	6.25	113	13983.75	38.31
	Fat	47.52	24	712	338342.40	926.97
	Total	131.18	66.25	-	584698.95	1601.91

Assuming that a peasant had one pig of these ages slaughtered per year, then the total addition to the diet would be 1,068-1,602 calories per day – over half of an individual's daily requirement (see Chapter 7), or 10-16% of the annual dietary intake for a family of five. It is easy to see why, from these results, that pigs have always been popular animals to keep in poor areas, if even a poorly-fed pig can potentially yield this many calories for a family.

6.3.2 Sheep and goats

Sheep and goats appear to have had an important role in small-scale mixed farming. According to Columella (*Rust*. 7.2.1) wool is the most important product from sheep, followed by cheese and milk, whilst goats were prized for their milk, meat and hair (White 1970a: 301, 314). Delano Smith (1979: 224), however, argues that wool would have only been of primary importance to the commercial farmer, whilst the average peasant would have thought of milk and cheese as the most important commodity.

Transhumance was a common feature in Roman sheep-rearing, and operated on both large- and small-scales. The system followed is important in this case as the composition of faunal remains from animals reared in this way would show different patterns to standard herds kept on farms. For example, static milk/wool herds that did not travel are likely to show a predominance of adult ewes. Short-distance transhumance herds are assumed to be similar as they are also geared towards subsistence but with an emphasis on milk and meat. Long distance transhumance, however, is argued to have been geared towards wool production, and records would show young males and some elderly sheep (both male and female) in winter grazing areas, and relatively few in summer grazing areas. In this study the subsistence model is assumed, either as static or short-distance transhumant herds. This would mean that consumption would focus on milk production with some meat (MacKinnon 2004a: 56). In the case of meat production of sheep and goats, it was recommended by Columella (*Rust*. 7.3.13) that lambs be slaughtered in order to make a profit from the mother's milk. Lambs were also sacrificed and often eaten, although in smaller numbers than pork (White 1970a: 310).

Despite its potential importance, we have no information on milk yields in the Roman period. We do know, however, that goats were capable of producing three or four times as much milk per weight than sheep (Billiard 1928: 336; in White 1970a: 315; Barker 1985: 43). This higher milk yield is mentioned by Virgil (*Georgics* 3.314ff) as well as the fact that it was preferred for drinking as well as for cheese. Modern yields (1961-2005) from sheep and goats are less distinct, with goats producing up to three times as much milk as sheep. In more recent periods this gap has lessened still, with nearly equal production per animal (FAOSTAT data 2006c), but this could be related to changes in technology improving sheep milk yields. However, given that faunal evidence has shown that goats were kept in fewer numbers than sheep (MacKinnon 2004a: 55), this would have evened out milk production between the two species (see also Varro *Rust*. 2.3.10). Faunal evidence from Monte Gelato showed the sheep:goat ratio in the Early Imperial period to have been 10:1, dropping dramatically to 1.75:1 in the medieval period (King 1997: 386)

Modern studies have shown that sheep's milk is also distinguished by higher milk fat and protein levels than either goat or cow milk (despite being volumetrically lower yielding), and has a higher cheese yield (Haenlein 2005; see also Table 6.15). This is supported by Varro (*Rust*. 2.11), who states that sheep's milk is the most nourishing, followed by goat. Whey could also be used to feed pigs (White 1970a: 211).

Modern milk yields from the FAO show that, in 1961, sheep milk yields were in the range of 71kg per year, rising to a maximum of 110kg per animal in 2005 (FAOSTAT data 2006c). Slicher van Bath (1963: 183) stated that the milk yield of sheep was one tenth that of a cow, and this has been interpreted as meaning that medieval milk yields were likely to have been in the range of 41.5-51.7 litres per year (Pearson 1997: 17). As one litre of sheep milk is equivalent to c.1.03kg this would mean an annual yield of around 42.75-53.25kg. These figures compare well (Table 6.12), and would seem to indicate a steady rise in yield, most likely due to animal selection and improved technology.

Table 6.15 Comparison of milk yields from sheep and goats from 1961 production figures (after FAOSTAT data 2006c) and Pearson (1997: 17; after Slicher van Bath 1963: 183)

	Annual milk yield	Calories per 100g	Annual calories	Daily calories
Sheep (1961)	71.1 kg	108	76,788	210
Goats (1961)	183.9 kg	69	126,891	348
Sheep (Pearson 1997)	42.75-53.25kg	108	46,170-57,510	126-158

Per animal, these milk yields would not have significantly contributed to the dietary intake of a Roman farmer and his family. One sheep, using Pearson's estimates would have contributed between 6-8% of one person's annual intake, or just 1-2% of a family of five. Goat yields (based on the 1961 FAO data) would have been higher, with one animal providing 17% of the dietary requirement for one person, or 3.5% for a family. However, according to the models of Delano-Smith (Section 6.3), small farmers with some land (model 2) could have kept up to half a dozen sheep plus 1-2 goats. This would have increased their input into the diet significantly.

From faunal evidence, Roman sheep stature is thought to have been smaller than modern breeds, but very similar to the medieval period. (Barker 1985: 42-43), though evidence from Monte Gelato showed the Late Roman sheep to be very slightly larger than the medieval assemblage from the same site (King 1997: 390). This is of less importance in this case, however. As this model is assuming consumption of mutton to be rare, with herds kept primarily for milk, the meat yield of caprines will not be incorporated.

6.3.3 Cattle

Studies of ancient agricultural systems have often included assessments of the contribution of cattle. Oxen were argued to not be economically viable on small farms and, even on larger farms such as that described by Varro (*Rust*. 1.20.4), their place as traction animals could be taken by the cow or donkey (White 1970a: 273). However, comparative evidence has shown that cattle may be shared by a number of smallholders (Lirb 1993; Halstead and O'Shea 1989), and as such provide vital products for the farmer.

There appear to have been a number of breeds of differing size and temperament, with six Italian and four foreign breeds mentioned in the Roman authors (Columella *Rust*. 6.1.1-2; Varro *Rust*. 2.5.9-11; White 1970a: 276). There has been a profound change in the size of cattle from prehistory to the modern period and, based on faunal evidence, Barker argues, though there is some variation across Europe, that Roman and medieval domesticated cattle would have been extremely small (Barker 1985: 30-31). Slicher Van Bath gives the average live weight of medieval European cattle as being *c*.200kgs (1963: 366), and we may expect that Roman cattle size would not be far different. This is compared to modern cattle that can reach weights of up to 700kg in the space of two years (Boatfield 1980: 29-30; in Barker 1985: 31)

Regarding the contribution of cattle to the Roman diet, White (1970a: 276) argued that Roman farmers had two aims in cattle production: firstly the production of good working animals, and secondly the production of attractive animals for sacrifice. Apart from White's reference to sacrificial meat, there is no direct evidence for the deliberate rearing of cattle for meat, although we know from Apicius that beef was consumed, if in small quantities (*De Re*

Coquinaria 1.11; 8.351-354). It has been argued that it was more likely that many animals would only have been slaughtered at the end of their working life, which would have meant tough and unpalatable meat. However, using comparative evidence it has been suggested that this might be an exaggeration and that the meat might not be that different in quality to younger cuts (Delano Smith 1979: 222). As such, the contribution of cattle to the diet may have been greater than was suggested by the textual evidence, either regarding milk or meat products. Further to this, it has been suggested that, if the number of identified specimens (NISP) and minimum number of individuals (MNI) figures are converted to "meat weight", then Roman assemblages would imply that they ate approximately the same amount of beef as they did pork (MacKinnon 2004b: 193-194; in Houston 2005).

This is where zooarchaeological evidence plays an important role. It has already been mentioned above that the age of slaughter for different types of husbandry (i.e. milk or meat herds) would have been different. Also, Barker argued that the lack of good quality fodder meant low returns on meat for a disproportionate amount of effort, and as such argued for the rearing of cattle on a small-scale for traction (Barker 1985: 31). This is supported by the faunal evidence from Monte Gelato, where oxen only appear in very small numbers and were raised to adulthood, implying their role as traction animals (King 1997: 389)

Though smallholders are likely to have kept (or had access to) oxen for traction, it is unlikely that their diet would have been reliant on their meat. Pigs are more likely to have filled that role. However, it is possible that farmers may have kept cows for milking purposes. It has been argued that cows were rarely used for milk production in Roman husbandry (White 1970a: 277; Barker 1985: 31). Cato never mentions cows' milk and, whilst discussing cheese, only mentions sheep (*de Agr*. 76-81). A statement by Pliny the Elder (*NH* 25.94) has also been interpreted as implying that consumption of cow's milk was unusual (White 1970a: 277). However, though this may have been the case for higher-status farmers, can we really assume that smallholders would not have exploited any food source available to them?

Varro, in contrast, specifically describes milch cows (*lactariis*, Rust. 2.1.17), and also pointed to more consumption of cow products in the following.

> *Of all the liquids we take for sustenance, milk is the most nourishing – first sheep's milk, and next goat's milk. Mare's milk, however, has the greatest purgative effect, secondly ass's milk, then cow's milk, and lastly goat's milk … of the cheeses which are made from this milk, those made of cow's milk have the most nutriment, but when eaten are discharged with most difficulty; next come those made of sheep's milk, while those made of goat's milk have the least nutriment and are most easily voided. There is also a difference depending on whether the cheeses are soft and fresh or dry and old…*
>
> Varro *Rust*. 2.11.3-4

This demonstrates that secondary products of cows were indeed consumed. Although this passage implies that cows' milk was recommended as a purgative rather than as food *per se*, this need not have been the opinion of all Romans, and could have been consumed as well as the cheese.

As for production figures, the agronomists do not provide any kind of statistics for milk yield. Modern production figures show that cattle can produce nearly 3000kg of milk per year, which adds an extremely significant element to the diet at 4,755 calories per day (Table 6.16).

Table 6.16 Comparison of milk yields from cows, from 1961 production figures (after FAOSTAT data 2006c) and Slicher van Bath (1963: 335, tab. V)

		Annual milk yield in kg	Calories per 100g	Annual calories	Daily calories
Cows (1961)		2845.119	61	1735522	4754.856
Cows (16th-19th C)*	Min	518.432	61	316243.6	866.4209
	Max	2073.729	61	1264975	3465.684
	Mean	1513.822	61	923431.4	2529.949

*converted from litres to kg using 1 litre = 1,036.864g

Historical records show European cattle to have produced between 518-2073kg (Table 6.16), and this gives a much broader range of milk production, contributing between 866-3,466 calories per day. This would equate to roughly 9-35% of the possible intake of a family of five. Obviously this is a far higher amount than can be produced by a single sheep, however, sheep could be kept in higher numbers, meaning a greater overall potential contribution to the diet.

6.4 Agricultural models for the Roman economy

The study of Roman agriculture is fundamental to our understanding of how Roman society functioned. How much food could be produced, and how much food was required to stay alive is consequently of prime importance. Modern scholars have disagreed on both crop yields and consumption in the Roman period. Now that I have discussed the available evidence for crop and animal yields, this section briefly outlines some of the models that have been posited in order to determine on what criteria they are based (Table 6.17).

Table 6.17 Comparison of production and consumption models

<table>
<tr><th>Source</th><th>Model</th><th>Date</th><th>Yield</th><th>Sowing rate</th><th>Plot size</th><th>Household</th><th>Daily ration in kcal</th></tr>
<tr><td>Ampolo 1980: 23-25</td><td>Latium</td><td>Archaic</td><td>4:1 / 3:1</td><td>5 and 10 modii</td><td>4 iugera (8 with fallow)</td><td>3</td><td>1,098</td></tr>
<tr><td colspan="8">*notes: Used mean of 4:1 and 3:1 yields with 5 and 10 modii ratios. 525kg per hectare / 131 kg/iug after seed / 70% remains after milling / usable wheat = 367kg per hectare. 120 kg/year ration</td></tr>
<tr><td>De Angelis 2000: 118</td><td>Sicily</td><td>Archaic/classical Greek</td><td>-</td><td>-</td><td>12-16 iugera</td><td>5</td><td>-</td></tr>
<tr><td colspan="8">*notes: assumption that three to four hectares of land (12-16 iugera) could support five people annually, regardless of quality</td></tr>
<tr><td>Rosenstein 2004: 66-68; 70-72</td><td>Small farms</td><td>Early Republic</td><td>3:1</td><td>5 modii</td><td>c.2.8-23.90 iugera</td><td>5</td><td>2,532-2,912</td></tr>
<tr><td colspan="8">*notes: A more complex model incorporates the cultivation of other field crops as well as a two iugera kitchen garden, orchard and vineyard. He only calculated the effect on the number of working days needed rather than the effect on production figures.</td></tr>
<tr><td>Beloch 1886: 415-418</td><td>Whole of Roman Italy</td><td>Late Republic</td><td>(6:1)</td><td>(5 modii)</td><td>8 iugera</td><td>6</td><td>2,471</td></tr>
<tr><td colspan="8">*notes: These figures led him to assert that nearly a quarter of the population probably relied on imports.</td></tr>
<tr><td>Brunt 1971a: 194</td><td>Veteran allotments</td><td>Late Republic</td><td>4:1</td><td>5-10 modii</td><td>c.30 iugera</td><td>4</td><td>1,158-2,315</td></tr>
<tr><td colspan="8">*notes: Deducted seed, and half of the land for alternate fallowing. Take no account of bad harvests or extra calories needed for heavy work. Assumes access to pasturage to supplement the diet or working as hired labourers on larger farms</td></tr>
<tr><td>Hopkins 1978: 21, 56 n.79</td><td>-</td><td>-</td><td>5:1</td><td>-</td><td>30 iugera</td><td>3.25</td><td>2,288</td></tr>
<tr><td colspan="8">*notes: Allows for no surplus or grazing land. Lies within the range postulated by Brunt above, and does not take into account other potential sources of food.</td></tr>
<tr><td>Jongman 1988; 2003</td><td>Whole of Roman Italy</td><td>1st C AD</td><td>4:1</td><td>5 modii</td><td>-</td><td></td><td>1,830</td></tr>
<tr><td colspan="8">*notes: Roman farmers in Italy were not in crisis due to the alleged over-cultivation of vines at the expense of wheat - quantify production totals of wheat, oil, and wine. 40% of the total land surface of Italy was used for agriculture (100,000km2). 75% under cereals. Doesn't account for imports. ¼ used for wine – plenty to satisfy demand</td></tr>
<tr><td>This model</td><td>South Etruria / Sabina</td><td>Early Imperial</td><td>2:1-15:1</td><td>5-10 modii</td><td>2 –240 iugera</td><td>Farms – 6
Villas – 25</td><td>1,951-3,798</td></tr>
<tr><td colspan="8">*notes: See Chapter 7 for dietary requirements</td></tr>
</table>

These models vary greatly, primarily due their different objectives. However, as pointed out by Garnsey (1988: 45) there is much more to a farm than the uniform yields and consumption patterns outlined in these models. Some of these models, particularly that of Jongman, include other foodstuffs, such as wine or oil on top of the wheat consumption. Farms varied in size, system of tenure, climate, soil fertility, crop cultivated, family structure, market relationship and external factors. All of these models assume a regular yield ratio across the area studied. As we know the geography of this country to have been widely diverse, this is a huge assumption, although often unavoidable in such models. However, using GIS it is possible to incorporate potential variation. A technique similar to those outlined above has been used below in the calculations presented here. However, instead of assuming a regular yield for the whole of the region, the various historical sources from Section 6.1 have been used to determine variations in crop yield.

One thing that all the previous models have in common is their tendency to use the lower yields from the sources. In most cases this is due to their need to model minimum production. For example, the most recent model by Rosenstein (2004) needed to model minimum production in order to gauge the most dramatic effect on a family's subsistence by the removal of adult males through warfare. This is not our intention here. Modelling the range of production statistics, rather than a minimum, enables us to ascertain the effects of changing food production levels on a population, and investigate under what circumstances non-agriculturally-productive populations might have problems due to food shortage. Before carrying out these analyses, however, the next stage is to determine the likely workload and subsequent dietary requirements of Roman farm labourers.

Whilst the previous chapter made a preliminary assessment of yields from hypothetical territories, this chapter looks at applying yields to the study area, with variable productivity, using the site locations as determined from field survey. A number of models are presented in this chapter, for different types of crops as well as mixed economies. These serve to highlight which sites are most suitable for which agricultural strategies and the maximum production figure they could have produced. This leads on to questions of surplus and urban provisioning, which are approached in Chapter 8.

6.5 Conclusions

The research into crop yields in this chapter feeds directly into the assessments at the end of Chapter 7 and in the main models of Chapter 8. Different economic strategies as well as agricultural techniques such as fallowing, rotation, and so forth will also be taken account of, and a number of models presented. The data produced here is far from complete however. There are many problems, primarily related to the lack of accurate yield data from antiquity for both crops and animals. The evidence for crop yields is less problematic than that for animals, yet using crop production alone to gauge consumption would be a flawed approach. By incorporating these figures, this study will provide a rough order of magnitude for animal product consumption and supplement any arable production in the area.

The numbers of different animals likely to have been kept by either villa owners or smallholders is an unknown quantity. Whilst we may model examples such as the 'Monte Gelato Model' (see Chapter 8.3.3) from the excavated faunal assemblages, there is no equivalent evidence for small farms. King (1999) has argued that the meat contribution to the diet of West Central Italy was primarily pork-based, yet these figures are largely based on excavations at high status sites such as the villas of Settefinestre or Monte Gelato. As such they may be representative of large-scale production for urban markets, particularly Rome, rather than the smallholder. From these assemblages sheep are argued to have low importance, but it has been noted elsewhere (Barker 1989; Thompson 1988) that the keeping of small herds and utilising short-distance transhumance is likely to have occurred. Due to this uncertainty, the models of Delano-Smith in Section 6.3 and the faunal assemblages will be used in conjunction with the 'yields' of meat or edible secondary products to establish potential consumption for farms and villas in the study area.

7 THE AGRICULTURAL WORKLOAD AND NUTRITIONAL REQUIREMENTS OF LABOURERS

This chapter approaches the evidence for workload and the subsequent food needs of the rural population. As has been noted in the previous chapter, a number of models have been put forward for agricultural production and supported populations. Such population estimates can only be carried out using a figure for calorific intake, and it was noted that this figure varied between studies (see particularly Table 7.4, page 304). However, nutritional requirements vary with the energy expended (amongst many other variables) and so evidence for both of these is assessed and compared to the previous models.

7.1 The Roman agricultural workload

In order to determine nutritional requirements, as well as probable cultivation strategies, we must now look to evidence for farm labour. One of the best pieces of evidence we have for the workload of a small farmer comes from the *Menologia Rustica* (agricultural calendars), which were found in Rome and could relate to practice in the area, although some have argued against this (e.g. Broughton 1936). As stated in Chapter 2, these inscriptions are thought to be the result of a long farming tradition, describing the annual activities of a small farmer of mixed husbandry, and probably date from the 1st century AD (Frayn 1979: 47-48; Chapter 2.2.1). The full translation of the *Menologium Rusticum Colotianum* from Rome is in Appendix I.

The calendars do not specify the number of days taken for each task, but does give an idea of the general workload, i.e. which tasks should be done when, and which were the busiest months (Table 7.1). The list of tasks may therefore help to determine how heavy the workload was for a small farmer of mixed husbandry.

Table 7.1 Agricultural tasks in the Menologium Rusticum Colotianum (ILS 8745, 1)

Month	Task
January	Stakes are sharpened
	Willow and reeds are cut
February	The grain fields are weeded
	The part of the vines above ground is tended
	Reeds are burned
March	The vines are propped up in trenched ground and pruned
	Three month wheat is sown
April	The lustration of the sheep is made
May	The grain fields are cleared of weeds
	The sheep are shorn and the wool is washed
	Young steers are put under the yoke
	The vetch for fodder is cut
	The lustration of the grain fields is made
June	The hay is mown
	The vines are cultivated
July	Barley and beans are harvested
August	The stakes are prepared
	Cereals are harvested, likewise the wheat
	The stubble is burned
September	The casks are smeared with pitch
	Fruits are gathered
	The earth around the trees is dug up
October	Grape gathering
November	Sowing of wheat and barley
	Digging of trenches for trees
December	The vines are manured
	Beans are sown
	Wood is cut
	Olives are gathered and also sold

This calendar highlights the variety in workload throughout the year. It has been stated that, in order to keep agricultural workers occupied for the whole year, it is necessary to cultivate a mixture of crops (Morley 1996: 123), and this is clear from the calendar above. Cereal monoculture alone is not sufficient to keep a workforce busy all year, and this is often still the case today for small farmers (White 1988: 224; O'Brien and Toniolo 1991). The calendar, however, demonstrates how activities such as harvesting can be spread out between July and December due to the different crops cultivated.

From the agronomists we have evidence regarding the amount of manpower necessary to cultivate certain crops, and these have been compared to other historical sources to test their validity. For cereal production, Columella states that per *iugerum* the workload takes up,

> *…four day's work of the ploughmen, one of the harrower, two of the hoer for the first hoeing and one for the second, one of the weeder, and one and a half of the reaper – a total of ten and one-half days of labour*
>
> *Rust*. 2.12.1

Columella next discusses the time taken to cultivate other crops (Table 7.2). From this he concludes that 200 *iugera* of land can be worked using two yoke of oxen, two ploughmen, and six labourers.

Table 7.2 Man-days required to cultivate different crops (after Columella Rust. 2.12.1-6)

Crop	Total man-days required per *iugerum*
Wheat	9.5-10.5
Spelt	9.5-10.5
Barley	6.5
Beans	7-8 (dependent on whether the ground is cultivated or fallow)
Vetch	3-4
Bitter vetch	6
Fenugreek	2-3?
Kidney beans	3-4?
Chickling vetch/small chickpea	6
Lentil	8
Lupine	3
Millet	10 (plus gathering)
Panic	10 (plus gathering)
Chickpea	11
Flaxseed	11
Sesame	15

In an article on the productivity of Roman agriculture, White compares Columella's calculations with later comparative sources (White 1965: 103). Columella's 9.5-10.5 man-days per *iugerum* for wheat is compared to 8 man-days per *iugerum* for 16th century England, 8 man-days for mid-20th century Paris (manual), and 13-16 man-days for early modern Cordova. White believes this similarity to have indicated a certain efficiency of production in the Roman period (assuming his figure to be trustworthy). The 10.5 days per year required to work one *iugerum* of arable annually, according to Columella, equates to 42 man-days per hectare per annum. This therefore implies that the maximum area that one man could effectively work per year if cultivating solely wheat was 8.7ha or 35 *iugera* – comparable to some of the larger veteran allotments.

For comparison with other crops, Columella states that viticulture requires 63 man-days per *iugerum*. This is much more labour-intensive, but again is comparable to statistics from modern vineyards in the Rhone Valley of 66 man-days (White 1970a: 373). Despite the higher labour demands than wheat, we have already seen that good profits may be made from much smaller enterprises (Chapter 6.1.3). The maximum plot workable by one man annually was consequently much lower than for wheat, at 5.8 *iugera*.

Columella's recommendations for a full working year for a slave workforce, regardless of crop, amounted to 250 days of labour, including 30 days for bad weather and public holidays, and 30 days of rest after sowing, which leaves a further 115 days of moderate farming and maintenance activities (see Table 7.6; *Rust*. 2.7.8-9). In his discussion of annual labour, White (1965: 102-103) observed that the 250 day working year of English farms in the 16th-18th century amounted to the same as that of the Roman period.

Table 7.3 Columella's working year (Rust. 2.7.8-9)

Activity	Workload	Days
Main agricultural tasks	Heavy	190
Bad weather / holidays	Moderate	30
Rest after sowing	Light	30
Remaining days	Moderate	115

It was noted that agricultural labourers from late 19th and early 20th century Italy worked approximately 265 days per year. Workers were not employed on Sundays, except during harvest, on religious holidays or at times of bad weather (O'Brien and Toniolo 1991: 397). In this period, it was argued that male farmers aged between 15 and 65 owned or rented enough land to occupy them all year (assuming a 265 day working year). However, landless male labourers, women, children and the elderly, were not believed to have worked a full year. The landless labourers worked only enough for 220 days only, and the remaining group worked only 120 days (O'Brien and Toniolo 1991: 398), implying that they must have either foraged or pursued other types of work throughout the year in order to feed themselves and any dependents.

This information is crucial to our model as workload is directly related to required nutritional intake. Applying Columella's workload statistics, which apply to slaves working on an estate, to the farming practice of both large and small-scale farmers could be considered problematic. However, the comparative evidence shown above and the Roman calendars would seem to support the general model of farming workload. This is also supported by Rosenstein (2004: 20), who argued that:

> *…the time and man-power figures* [Varro and Columella] *preserve, it is true, are for slaves labouring on large estates, but, as noted, there is no reason to believe that small farmers would not, if necessary, have worked as hard or harder in order to feed themselves.*

7.2 Nutritional requirements of Roman labourers

It is impossible to know exactly how much food was consumed by Roman populations, as this would vary hugely according to one's level of wealth and status, and on seasonal fluctuations of production. However, there are indicators from a number of sources that may help us to determine the probable nutritional requirements of certain groups. Nutritional requirements can vary immensely due to a number of different factors, such as age, sex, height and weight, level of activity and so on. In order to gauge the possible subsistence level of the settlers in the study area, it was necessary to establish a general model of subsistence based on both historical and contemporary data. The FAO has published a number of studies on human nutritional requirements (the main publications being FAO 1973a; 1985) and these are compared and adjusted in this chapter according to data from our sources, alongside studies of contemporary populations. Energy requirements are defined as being,

> *…the amount needed to maintain health, growth, and an 'appropriate' level of physical activity.*
>
> FAO 1985: section 2

The nutritional requirements of the Romans are therefore based on two factors: the nutritional levels *recommended* for certain groups, and the *observed* levels from known groups both historically and anthropologically. Intake is measured in kilocalories (kcals), although these will henceforth be referred to as 'calories'.

7.2.1 Diet and subsistence requirements

The majority of studies on agriculture and food supply must, by default, incorporate some study of ancient diet. Many of these studies are outlined in the section on agricultural models (Chapter 7.3). This is due to the intrinsic link between agriculture and population subsistence. For an overview of the variety of subsistence requirements used in these studies, see Table 7.4

below. Generally, this intake has been based around the consumption of grain, due to the importance of this as a staple in Roman diets, as suggested by the large passages devoted to grain by the agronomists (White 1988: 218). It has been asserted that Roman subsistence equates well with modern (Evans 1981: 433), and both ancient and modern figures will therefore be compared and used to determine a standard subsistence level for this study.

Table 7.4 Comparison of different nutritional requirements used by a selection of historical studies

Source	Daily subsistence in kcal	
Beloch (1886)	2,471	
Brunt (1971)	1,853	
Hopkins (1978)	2,288	
Foxhall and Forbes (1982)	3,337	Very active men
	2,852	Moderately active men
	2,583	Average for household of 6
Gallant (1991)	3,000	Adult men
	2,200	Adult women
Jongman (2003)	1,830	
Garnsey (1999)	1,625-2,012	Uses Clark and Haswell's figures

Clark and Haswell (1970: 58-59) carried out studies of a variety of modern peasant populations across Africa, Asia and China, and concluded that the range of calorific requirements for subsistence was between 1,625 and 2,012 calories per day, depending on the length of the working day, stature, climate and other associated factors. They also argued, however, that even the poorest societies craved variety in their diet, and so would include foodstuffs such as olive oil, wine, fruit and vegetables.

It can be seen from Table 7.4 that estimates of subsistence levels have varied greatly between studies. In a comparison with the modern figures we also see that the figures used for antiquity are higher in general than those of modern rural populations as put forward by Clark and Haswell. This is primarily because many of the studies follow the FAO guidelines for nutritional requirements, but use figures for different sectors of society with different energy expenditure. This is with the exception of Garnsey, who follows Clark and Haswell's recommendations, although he does point out that these low figures are minimum requirements to support life rather than retain good health (Garnsey 1999: 19-20). In their major study of the role of grain in the Roman diet, Foxhall and Forbes strongly emphasised that figures such as those in Table 7.4 are merely yardsticks against which to compare data. People did not necessarily consume as much as they physically required to remain healthy and there were likely to have been great differences between different income groups (Foxhall and Forbes 1982: 50).

One of the earliest studies of this type was by Beloch (1886: 393-412; in Foxhall and Forbes 1982: 70) who estimated that 3 ⅓ *modii* was the amount of grain consumed per person in the Roman period, although it is not clear on what this assumption is based on. This amounts to approximately 2,471 calories per day. This figure was also used by Rickman to estimate the total figure for annual grain consumption in Rome (Rickman 1980: 10).

Brunt, (1971a: 194) argued that 120 *modii* of wheat would produce enough to feed a family of four for one year, which equates to approximately 1,853 calories each per day. Obviously here, some members of the family will consume more than others, depending on their workload and status, and so this figure is merely an average consumption figure for the whole family group. This was also assumed by Hopkins (1978), although his given subsistence for a family was higher at 2,288 calories per person per day.

In their study of Graeco-Roman grain consumption, Foxhall and Forbes (1982: 49) quoted the FAO (1973a: 25) statistics that a very active man requires 3,337 calories per day, whilst a moderately active man requires only 2,852 calories. These are again higher than the subsistence levels given in the previous studies, but this does relate to requirements to maintain a good level of physical health, as opposed to what people may actually have received in reality. This study also differentiated between age and gender as regards calorific consumption. They used a household consisting of six people to determine a family's total consumption.

Gallant, in his study of risk avoidance strategies in ancient Greek agriculture, utilised data from Foxhall and Forbes' study, as well as from official publications. He arrived at a different maximum of 3,000 calories daily for adult men and 2,200 calories for adult women (2,500 if pregnant). He also derived differential figures for people of different age and gender, and these are outlined in the table below. We can see that his maximum figures are not far removed from those of Foxhall and Forbes, whilst his minimum figures for very young children are similar to those given by Brunt and Jongman for adults (Table 7.5).

Table 7.5 Dietary requirements dependent on age (after Gallant 1991: 73, tab. 4.5; and Foxhall and Forbes 1982: 49, n.26)

Age	Male	Female
4-6	1,830	1,830
7-9	2,190	2,190
10-12	2,600	2,350
13-15	2,900	2,490
16-19	3,070	2,310
20-39	3,000	2,200 (2,500 if pregnant)

Table 7.6 Dietary requirements of a household (after Gallant 1991: 73, tab. 4.5; and Foxhall and Forbes 1982: 49, n.26)

Age	Male	Female
7-9	2190*	-
10-12	-	2350
13-15	3237	-
20-39	3337	2434
60-69	-	1947
Total household consumption	15,495	
Average ration	2,583	

* The child aged between 7-9 is of unknown gender

These household figures (Table 7.6) are considered by Foxhall and Forbes to be on the high side. The FAO's figures for children's nutritional requirements are argued to be over-generous, and Foxhall and Forbes consider that the average Roman household was likely to have consisted of more children and fewer adults, thereby lowering the total figure required (Foxhall and Forbes 1982: 71). These ranges of calorific intakes will be returned to in Section 7.2.4.

Though nutritional requirements have been discussed above, these were primarily based on modern requirements. Actual consumption figures from antiquity for any foodstuff are rare. The first, used by Foxhall and Forbes (1982), is from Polybius (6.39) and outlines the rations of the Roman army in the mid 2nd century BC (Table 7.7). The cavalry figures have very high rations compared to that of the infantry, and Foxhall and Forbes suggested that this was because the ration included food for a groom. It was therefore surmised that the infantry ration fed one man, the Allied cavalry two, and the Roman cavalry three, and this is borne out if one divides the rations in such a fashion (Walbank 1957: 722; in Foxhall and Forbes 1982: 62-63).

Table 7.7 Monthly rations for Roman soldiers according to Polybius (after Foxhall and Forbes 1982: 86-89, tab. 3)

Unit	Ration	Wheat (in kg)	Per person	Daily calories
Roman and allied infantry	2/3 attic *medimnos*	26.9	327	2,990
Roman cavalry	2 *medimnoi*	80.56	980	8,969
Allied cavalry	1 1/3 *medimnoi*	53.7	653	5,979

The tablets from Vindolanda give various accounts of wheat quantities for army personnel, with evidence for the source and distribution of supplies, as well as trade (e.g. TVII 180, 182, 186; Bowman and Thomas 1994: 32-35). However, although many of the tablets are well preserved, they are lacking information such as that given by Polybius – i.e. how many soldiers the food was intended for. A more useful source comes from a series of ink-written tablets from a late 1st century AD fort at Carlisle, which give evidence for the consumption of wheat and barley by a cavalry regiment in Roman Britain (Tomlin 1998). Tablet 1A (see Table 7.8) is thought to record three days-worth of rations for a *turma*. It is unsure as to how many men were included in a *turma*, but it was suggested to have been 33 men – one decurion, two under-officers, and thirty troopers (Tomlin 1998: 46-47). As with Foxhall and Forbes, it was assumed that the barley was meant to feed the horses rather than the soldiers (Tomlin 1998: 45; Foxhall and Forbes 1982: 88).

These rations seem very high, especially as this was expected to form only part of the diet. The Vindolanda tablets, for example, show evidence for foodstuffs such as beans (TVII 192), bacon and pork (TVII 182, 186), bacon and pork fat (TVII 182, 190), beer (TVII 186, 190), wine lees (TVII 185), wine (TVII 190), goat meat (TVII 186), fish-sauce (TVII 190), honey (TVII 192) spices, eggs and gruel (TVII 193). The unknown variables involved in such calculations therefore cause problems in determining the actual ration. It could be that either the food was meant for larger numbers of people, or alternatively to last for longer than three days. For example, if we extend the suggested ration period to six rather than three days, the figures are closer to the 2,990 calories of the Roman infantry from Polybius (Table 7.8).

Table 7.8 Transcription of Carlisle tablet 1A assuming 33 men per turma and rations for both 3 and 6 day models (after Tomlin 1998: 44, tab. 44)

Name of decurion	Barley (in *modii*)	Wheat (in *modii*)	Wheat (in kg)	Wheat (kcals)	Calories per day (3-day)	Calories per day (6-day)
Genialis	42	18	121.5	405,810	4,099	2,050
Agilis	39	18	121.5	405,810	4,099	2,050
Albinus	45	18	121.5	405,810	4,099	2,050
Gentilis	33	15	101.25	338,175	3,416	1,708
Peculiaris	33	15	101.25	338,175	3,416	1,708
Pacatus	39	15	101.25	338,175	3,416	1,708
[ ]	36	15	101.25	338,175	3,416	1,708
[ ]	60	18	121.5	405,810	4,099	2,050
Se[..]us	33	15	101.25	338,175	3,416	1,708
Sodalis	36	15	101.25	338,175	3,416	1,708
Docilis	45	[18]	121.5	405,810	4,099	2,050
[Sollemnis]	[45]	[18]	121.5	405,810	4,099	2,050
Mansuetus	42	18	121.5	405,810	4,099	2,050
Martialis	30	15	101.25	338,175	3,416	1,708
Genialis	39	18	121.5	405,810	4,099	2,050
Victor	45	18	121.5	405810	4,099	2,050
'for Pacatus, decurion'	27		-	-	-	-
Total	669	267	1802.25	6019515		

The final piece of evidence from the Roman agronomist Cato is also complex, though does at least refer to farming rather than the military diet. The passage in question (*de Agr.* 56) outlined annual rations for his slaves that consisted of grain, oil and wine. It is not specifically stated what period of time these rations were supposed to last for, although it has been assumed that these were monthly, based on the calorific content (Foxhall and Forbes

1982: 63). The cereal rations are discussed in more detail below but, as an overview, consisted of between 2,223 and 3,335 calories per day, dependent on the workload. Olive oil was rationed at around half a litre per month (Cato *de Agr*. 58), which equates to approximately 133 calories per day. It must also be pointed out, however, that oil had uses other than as food, and so this ration may include sufficient oil for other domestic purposes. Finally, the total annual wine consumption was around 181 litres annually (Cato *de Agr*. 57), which meant a consumption of approximately half a litre a day, or 352 calories according to Foxhall and Forbes estimation of 586 calories per 0.8 litres of wine (1982: 58). This meant a total daily consumption of between 2,708 and 3,820 calories.

Two other ancient references both give rations of 5 *modii* of grain per month, or the equivalent of 3,706 calories daily. Seneca (*Ep.* 80.7) gives this as the ration for a slave, whilst Sallust (*Historiae* 3.48.19) states that this is the allowance of the *Lex Frumentaria*.

> *By this law they have valued the liberty of all of you at five [modii] per man, an allowance not much greater than prison rations. For just as in the case of prisoners that meagre supply keeps death away, yet their strength wanes…*

It is, despite this negative view, a generous ration for one person, but we do not know how many people this was intended to feed. We can assume that the dole, at least, was intended for consumption by a family rather than an individual, making the ration far less generous than at first glance.

7.2.2 Composition of the diet

The ancient diet was not restricted to grain consumption, and could also be made up of a number of other foodstuffs. The basic diet of the Romans in this region is thought to have consisted mainly of the 'Mediterranean Triad' of cereals, olives and wine, which had been cultivated since the late 8th and early 7th centuries BC (van Joolen 2003: 110). Along with the fig, the olive tree and vine were considered so important in the Roman period that they were planted symbolically in the *Forum Romanum* (Brothwell 1988: 254). This 'triad' has since been augmented by Garnsey (1999: 15) who added dry legumes such as broad beans, chickpeas, lentils and peas, as a dietary staple. Foxhall and Forbes (1982: 45, n.10) also added to this the consumption of vegetables, wild greens and fruit, based on the literary sources.

There have been various discussions on the content of a typical Roman diet. Gallant (1991: 68), in his discussion of the ancient Greek peasantry, postulates that between 65-70% of the diet was made up of cereals, 20-25% of vegetables and fruits, and 5-15% of oil, meat and wine. Foxhall and Forbes (1982: 74) suggest that 70-75% of the Greco-Roman peasant's diet consisted of cereals, but were less specific about what made up the remaining calories. They claimed that foods such as wild greens, mushrooms, bulbs, pickled olives, dried figs, and other vegetables were consumed to provide some dietary variety, but did not give specific quantities.

Consuming mainly a wheat-based diet has been thought to have been detrimental to health, and asserted as being almost totally deficient in vitamins (Rickman 1980: 7). However, wheat actually contributes a large number of the essential nutrients and so a largely grain-based diet was actually not as bad as has been postulated. Children can develop normally on primarily cereal-based diets with little or no meat, though have lower rates of growth if lacking dairy products. Any nutritional deficiencies are likely to be related to low iron or vitamin B_{12} (Sanders 1999: 267-268). Consequently, the consumption of garden vegetables and salad plants could be argued to provide primarily variety and taste to an ordinarily bland cereal-based diet, rather than contribute any significant nutrients, likewise the use of condiments and herbs (cf. pseudo-Virgil *Moretum*, Chapter 2.2.1; White 1988: 237; Garnsey 1999: 20).

The consumption of fruits also did not necessarily contribute much in a calorific sense (although some had a high nutritional value), but instead added variety and an attractive sweet taste. However, citrus fruits were very restricted in consumption in this period, only becoming common in the medieval period (Brothwell 1988: 250, 253-254). Other fruits were more common, with references to certain towns being known for their produce (e.g. Falerii Novi, see Chapter 2.2.2). However, we do not hear of fruit as food for the lower classes, though this could just be due to the inherent bias in the ancient sources. The exception here, though is figs; Cato even reduced his grain ration for his slaves when the figs were ripe (*de Agr*. 56), and so it is possible that the lower classes would have consumed fruit, though we cannot know to what extent.

Investigating the rations of Cato's slaves further, if we use the minimum grain consumption, this would mean that the proportions of their ancient diet consisted of 82% grain, 5% olive oil, and 13% wine. Jongman (1988: 79-80) also arrives at similar figures from these results with 5% for oil, but between 10-15% for wine, leaving grain at between 80-85% of the ancient diet. Jongman's calorific calculation for the consumption of wine was between 350-500 calories per day.

Figures from a number of historical studies (Table 7.9) show that a large percentage of the diet was assumed to have been made up of cereals (between 65 and 90%). It is likely that peasant farmers would have had a more varied diet than merely grain, oil and wine, as we know from the pseudo-Virgilian poem *Moretum*, as well as other sources (see Chapter 6). Produce from kitchen gardens, a limited amount of dairy and meat, as well as forage foods would have likely played a role, thereby reducing the percentage intake of grain to the lower end of this scale. Although not a staple food, wild plants were an important addition to the diets of the poor, adding variety and additional nutrition (Garnsey 1999: 36-37; Frayn 1979: 57-72).

Table 7.9 Comparison of dietary proportions suggested by historical studies

	Recipient	Grain	Oil	Wine	Vegetables and fruits	Oil, meat and wine
Cato (my calculation based on calories from Cato's rations)	Slaves	82-87%	3-5%	9-13%	-	-
Cato (Jongman 1988: 79-80)	Slaves	80-85%	5%	10-15%	-	-
Gallant (1991: 68)	Ancient Greek peasant	65-70%	-	-	20-25%	5-15%
White (1988: 236)	Antiquity	70-75%	?	?	?	?
Brothwell (1988: 247)	Greece and Rome	70%	?	?	?	?
Forbes and Foxhall (1982: 74)	Average classical diet	70-75%	?	?	?	?
Garnsey and Whittaker (1983: 118-130)	Antiquity	70-75%	?	?	?	?
Garnsey 1999:12	S. Italy 1960s	60%	30%	?	?	?

This compares favourably to modern consumption patterns in Southern Italy from the 1960s quoted by Garnsey (1999: 12). He states that in this period 60% of the total energy intake is derived from cereals, whilst less than 30% is from fats, particularly olive oil. Roman olive oil consumption across the Mediterranean has been estimated as *c*.20 litres per head (Mattingly 1988a: 33-34; 1996: 223, 239). Assuming it was all eaten (a big assumption given its other uses, e.g. lighting and personal hygiene), this would contribute approximately 442 calories per day, higher than Cato's rations. However, we still do not know how likely Roman populations were to receive the amount of energy and protein required to retain good health.

7.2.3 Diet and health as established from faunal and skeletal analysis

Nutrition is problematic to calculate from written evidence alone. For this, skeletal analysis plays the most important role. However, as pointed out by Dyson (1992: 182), although thousands of Roman skeletons have been discovered during excavations in Italy over the years, little or no information regarding them has ever been published. Recent exceptions to this are mentioned below.

Skeletal analysis, be it human or animal in origin, is very useful in deciphering elements of the ancient diet. Firstly, animal bones in archaeological contexts can provide clues to past diets as we can look at the sheer numbers appearing in different places and periods (Chapters 5.7 and 6.3).

Regarding human skeletal remains, a number of different analyses may be performed to give a variety of information regarding diet and nutrition. Firstly, age at death is an obvious factor, but also the presence of defects often point to malnutrition or associated diseases (Dyson 1992: 182). Stature, for example, is determined by the quality of one's nutritional intake during development, and so if this may be ascertained from bone assemblages this will add greatly to our knowledge of the standard of the Roman diet (Garnsey 1999: 52). Cemetery samples, however, are prone to bias; not least because of the practice of both inhumation and cremation in Italy. As an additional problem, it is only the inhabitants of towns that tended to be buried in cemeteries, and rural settlers are argued to have often been buried on their own farms (Dyson 1992: 147). This means that any information gleaned from such sources may not representative of the population as a whole, and certainly not the sector that we are interested in here.

Deficiency diseases did not just affect the poorer classes. Deficiencies in vitamins A and D as well as practices concerning weaning, would have led to a variety of eye diseases, rickets or bladder-stone conditions in all levels of society (Garnsey 1999: 45-48). Skeletal samples from the Necropolis of Vallerano, in the suburbs of Rome (2^{nd}-3^{rd} century AD), for example, indicated that the majority of suburban dwellers suffered with conditions such as developmental problems and parasitic infection (Cucina *et al.* 2006).

The relative amounts of different types of food consumed have been variously estimated, as outlined above (Section 7.2.2), and these are based on either historical or anthropological information. Estimates of grain consumption have a significant role in studies of ancient demography, trade and agriculture (Section 7.3) and consequently, a relatively new form of analysis may have important implications in this area. Isotopic analysis has been used since the 1970s to study the proportions of stable isotopes found within bone. This type of analysis can identify to a certain degree the main elements of diet. This works by measuring the concentrations of certain elements in the bone collagen, which reflect mainly the protein part of the diet. Also, given the long turnover rate of collagen, also reflects long-term dietary habits of approximately ten years.

To illustrate what may be achieved, the proportions of meat to vegetables may be ascertained using the levels of strontium concentrations within the bone (Richards *et al.* 1998: 1248;

Lewin 1983). This type of analysis has, until recently, been applied mostly to prehistoric assemblages. However, two recent studies have been carried out on Roman assemblages – one on a site near the Roman port-town of Portus Romae, just outside of the study area (Prowse *et al.* 2004), and the other in Britain at the Roman cemetery of Poundbury, outside Dorchester (Richards *et al.* 1998). These studies, although of great importance to a general study of Roman diet, were unfortunately not applicable to our study area. Due to the position of the cemeteries studied – on the Tyrrhenian coast at the mouth of the Tiber, and near the coast in southern Britain – the sample is biased towards consumers of marine food, as opposed to the predominantly terrestrial diet one would expect from an agricultural community. Also, given the high status of many of the burials, we are not likely to be getting results from a good cross-section of the society.

The faunal data from the excavated settlements nearby indicated high numbers of animal bone (Buckland-Wright 1987). With nearly 3,500 specimens from the late 1st century assemblage and a dominance of cattle and caprines used primarily for their secondary products, it demonstrates the problems in using animal bones to determine overall dietary patterns for an area. The isotope study showed some element of status differentiation, as it was found that people in lower status graves had different diets to those found in higher status ones (Richards *et al.* 1998: 1249-1250). This therefore shows that the low-status urban diet of Roman Britain tended towards consumption of plant foods (either cultivated or forage) with a varying amount of meat, probably according to wealth, a pattern that could not have been determined from the faunal assemblage alone.

Given these interesting results, one may hope that more such studies will be carried out on different historical periods and areas and, if possible, on different sections of the community. The study of remains from rural contexts rather than urban, is also likely to affect the results.

7.2.4 Determining dietary requirements for a Roman agricultural labourer

A number of factors are required in order to gauge potential nutritional requirements – height, weight and level of activity. The only factor for which we have archaeological evidence is height, as knowledge of stature may be derived from skeletal assemblages. Humans, however, are diverse in their physiological characteristics, and so it is unlikely that we would be able to determine a 'typical' stature for Roman adult men and women or children. Various factors, both physical and socio-economic, influence height, including diet, disease, work intensity, income, and genetics (Steckel 1995: 1908, fig. 1). However, for a study such as this, some assessment of a generalised stature is required to gauge some idea of potential nutritional requirements. By assessing the range of stature ascertained from different samples, we may test the effects that these different statures have on energy needs. A 'typical' nutritional requirement is not useful in this instance, instead a range is estimated and used for minimum and maximum needs.

The nutritional requirement of 3,337 calories per day by Foxhall and Forbes for ancient Greece was derived using figures for a male, aged between 20-29, around 1.62m in height, and weighing 62kg (Foxhall and Forbes 1982: 48-49). However, as this was based on Greek evidence, these were altered to reflect the Roman data. Studies of skeletal remains are outlined in Table 7.10 below, along with other sources of height data.

Garnsey (1999: 52) has argued that the elite were likely to have been taller than the poorer classes, and this has been backed up by ethnographic research which has shown differences of up to 10cm between rich and poor (Steckel 1995: 1915, tab. 4). The shorter stature of Italians in 1927 shown in the table, for example, has been attributed to the poverty of the country in the early 20th century (Arcaleni 2006).

Table 7.10 Height data for Italy, arranged by region

Region	Sample	Height in cm	
		Men	Women
Campania	Herculaneum (Bisel 1988: 64, tab. 2)	169	155
	Pompeii (Lazer 1995: 203; in Garnsey 1999: 58)	167.6	154.7
	Military conscripts Campania 1927 (Arcaleni 2006: tab. 1)	164.9	-
	Modern Naples 1960s (Bisel 1988: 63)	164	152.6
Lazio	Isola Sacra (Prowse *et al.* 2004)	163.5	152.4
	Military conscripts Lazio 1927 (Arcaleni 2006: tab. 1)	167.62	-
Italy (national)	Military conscripts Italy 1927 (Arcaleni 2006: tab. 1)	166.95	-
	Range	163.5-172	152.4-164

Weight is more difficult to estimate, particularly as it is dependent on a number of factors, including gender, height, and nutritional status. We may therefore use the Body Mass Index to determine potential ranges of weights based on height. According to the National Health Service (NHS 2004) a healthy Body Mass Index is between 20 and 25. Weight is then determined using the formula:

$$\text{Weight in kg} = (\text{height}^2 / 10000) * \text{Body Mass Index}$$

Of course we cannot know that the rural population would have maintained a healthy weight, particularly given the uncertainties of food supply in this period. What we may deduce, however, is that were people to have subsisted at unhealthy levels of under-nourishment, more people would have been supported by the production of the study area. Minimum and maximum weights are therefore established for the height ranges (see below).

Energy requirements vary depending on the Basal Metabolic Rate (BMR) of the person in question. The higher the activity level, the greater the BMR and subsequently the energy required. The standard method of calculation for BMR is the Harris-Benedict formula (Harris and Benedict 1919).

BMR (per day) = 66.4730 + (13.7516 * weight in kilos) + (5.0033 * height in cm) - (6.7550 * age in years)

To illustrate, the BMR used in this example was based on a male, aged 25, 163cm tall, and weighing 60 kilograms. In this instance the weight was based around the 'healthy' weight of a man of medium build of that height, based on the mid-range of a healthy Body Mass Index (22.5). Using the weight of 60 kg the equation is therefore:

BMR (per day) = 66.4730 + (13.7516 * 60 kg) + (5.0033 * 163 cm) - (6.7550 * 25 years)

BMR (per day) = 1,535
BMR (per hour) = 63.97

Once the average hourly BMR of 63.97 was established, this was then used in conjunction with the FAO figures (1985: tab. 9-11) to estimate the required daily energy intake for different workloads (Table 7.11).

Table 7.11 Daily nutritional requirements of a hypothetical Roman farmer assuming a nine-hour working day and different workloads (after FAO 1985: tab. 9-11)

Daily activity	BMR	Hours	Calories required dependent on workload		
			Light	Moderate	Heavy
In bed at 1.0 × BMR	63.97	8	511.76	511.76	511.76
Occupational activities at 1.7/2.7/3.8 BMR	63.97	9	978.74	1554.47	2187.77
Socially desirable and household tasks at 3.0 × BMR	63.97	3	575.73	575.73	575.73
Residual time at 1.4 BMR	63.97	4	358.23	358.23	358.23
Totals based on my BMR calculation		24	2,425	3,000	3,634

These divisions of the day are based on the FAO data, though adjusted for length of working day. Clark and Haswell (1970: 14-16) give examples of between 3-8.5 hour working days for peasant societies. Foxhall and Forbes (1982: 48, n.24) note this example, and that in fact, it is impossible to know the length of the working day in antiquity. However, the ethnographic parallels provide a maximum working day of 8.5 hours, and therefore a maximum of nine hours was used in the models to incorporate the possibility of longer days for Roman labourers. A shorter working day – the minimum of three hours heavy labour – was also modelled to gauge the differences in intake for different working practice. The results showed that the nine-hour working day required 2,425-3,634 kcal, whilst the three-hour day required 2,309-2,712kcal (see Appendix VI, Tables VI.3-6, Figure 7.1).

The next stage was to apply figures for different workloads to the agricultural year. Columella's recommendations for a 250-day working year amounted to 190 days of labour, plus 30 days for bad weather and public holidays, and 30 days of rest after sowing, leaving a further 115 days of moderate farming and maintenance activities (*Rust*. 2.7.8-9). This can be translated into the following energy requirements assuming a nine-hour working day (Table 7.12).

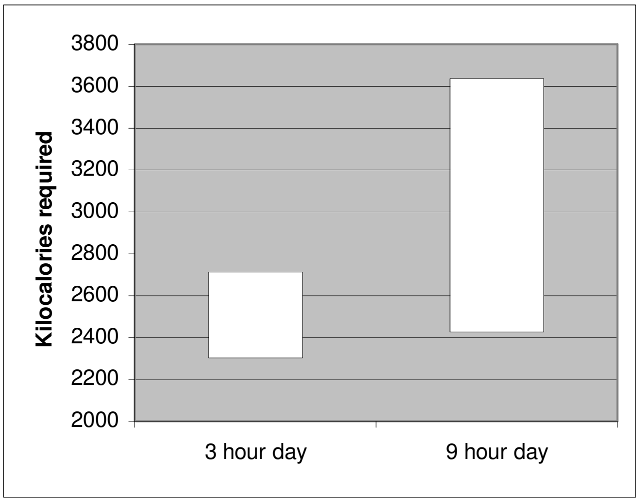


Figure 7.1 Comparison of three-hour and nine-hour days regarding calories required

Table 7.12 Annual energy requirements of a Roman farmer based on workload from Columella's calculations, rations from Cato, and FAO statistics

Columella's working year	Workload	Days	FAO Energy requirement in kcal	Energy (kcal) Cato's slaves	Energy (kcal) Forbes and Foxhall
Main agricultural tasks	Heavy	190	690364.2	725800	-
Bad weather / holidays	Moderate	30	90005.79	103500	-
Rest after sowing	Light	30	72733.89	81270	-
Remaining days	Moderate	115	345022.2	396750	-
Total annual energy required			1,198,126	1,307,320	1,218,005
Mean daily energy required			3,283	3,582	3,337

The fifth column in Table 7.12 shows the equivalent calorific intake for Cato's slaves (*de Agr.* 56, see Section 7.2.2). This is derived purely from the text, applying the calorific equivalent of the foods specified, rather than using the FAO statistics. Cato states that his rations for slaves entailed three *modii* of wheat per month (2,223kcal), or 4.5 *modii* (3,335kcal) if the work was particularly heavy, with additional wine (352kcal) and oil (133kcal) rations.

Applying this to the calculations above would mean a total annual consumption of 1,307,320 calories. This is more than that required by the FAO according to my own calculations and more than Foxhall and Forbes' requirement for very active men. These figures equate to an average daily allowance of 3,582 calories for Cato's slaves and 3,283 calories per day according to my own calculations based on the FAO data. These figures would seem to indicate a requirement for high consumption of foodstuffs, though my own calculations are lower than those of Foxhall and Forbes (3,337kcal).

These comparisons are problematic in one respect, as we cannot know what Cato or Columella considered to be heavy or light work. Also, we do not know how hard Cato worked his slaves on a daily basis, though it is hoped that by modelling the three- and nine-hour day this problem may be alleviated to some extent. Furthermore, a Roman peasant farmer, responsible for his own subsistence, may not actually *receive* his recommended daily requirement. 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 as much as they need. According to Campbell (1978: 49), however, recommended intakes are,

> *…based on an estimation of the mean minimum amounts necessary to prevent deficiency symptoms or to meet other suitable criteria.*

Because of variation between individuals a certain percentage will fail to meet the recommended daily intake, and not all that do meet it will necessarily be well nourished.

With this in mind, the calculation based around the FAO figures (1,198,126 calories annually) seems to represent a fairly good average of consumption for adult males. Adult males, however, were not the only members of the rural population. Therefore, we must also quantify likely nutritional requirements for adult females. If we continue to use the Isola

Sacra data, with a height of 1.52m (Table 7.13), the healthy weight of a woman would be approximately 52kg, thus making her hourly BMR 57.21, and her annual calorific consumption 847,194-1,071,515 calories. This assumes the same workload as the men, which is common in peasant societies (FAO 1985: section 4.4). This is assumed by scholars such as Scheidel (1995; 1996) and Garnsey (1999: 111) to have been the case in antiquity also, given the practice in comparative societies, and the need for manpower at crucial times, such as the harvest. There is little contemporary Roman evidence for women's role in production. It has been argued however that, due to the large rural population engaged in agriculture at this time, it is likely that women would have been involved. This is particularly as many were operating at a basic subsistence level, and productivity was thought to have been generally low. Many also lost their husbands or sons to military service, and either had to cultivate their own land, or hire themselves out as wage-labourers (Scheidel 1995: 207, 211-213). Scheidel (1995: 208) goes on to argue that:

> *…an absolute majority of all women in the Graeco-Roman world either belonged to households that lived by agriculture and had, at least at times, to rely on the labour of all its members, or were compelled as slaves or dependents to fulfil whatever tasks they were assigned.*

It has been argued that in the Roman patriarchal society, women would have received less food than the males, as they were believed to require a lesser amount (Garnsey 1999: 101, 103). Above, however, we can see that women's nutritional requirements were indeed likely to be lower, despite having the same potential workload. This is mainly due to the difference in stature, and so differences in food distribution within a household would not necessarily be problematic, unless pregnant or lactating. If one assumes an equal division of labour and an equal population split, then the two figures for calorific intake, for men and women, must be averaged to give an overall figure for the nutritional requirements of all adults. In the case of the typical adult male and female this equates to 2,458-3,109kcal, depending on the length of the working day.

This assessment was then repeated with different stature, weight, and age ranges. The effects of age, different stature and weight on nutritional requirement were ascertained using the same system as above, including intake for the undernourished. The full list may be seen in Appendix VI, but the general rule was that older people required less food than the young, along with smaller and lighter people, as would be expected. Table 7.13 shows the worst and best case scenarios for food intake, a) being the smallest, oldest, and most malnourished, and b) being tallest, youngest and at the top of the healthy BMI range. A shorter working day of three hours was used for the 'worst' case figures.

Table 7.13 A) Worst- and B) best-case scenarios for food intake in kilocalories

	Men		Women		Both	
	Min	Max	Min	Max	Min	Max
3 hour day	2068.89	3115.17	1832.36	2891.29	1950.63	3003.23
9 hour day	2616.69	3940.00	2317.53	3656.84	2467.11	3798.42
Difference	547.80	824.84	485.17	765.56	516.49	795.20

The ranges gained from the different variables as outlined above would give an overall mean range of 1,951-3,798 calories for both men and women aged between 15 and 45. This included BMI figures for the underweight up to the upper range of a healthy person. The difference between the lower and upper range is 1,848 calories daily, which could impact heavily the numbers supported within our model. Rather than use a mean figure for requirements, this range will therefore be used in further analysis to give minimum and maximum supported population for each model.

7.3 Determining supported populations for hypothetical sites

From the historical yield statistics assessed in Chapter 6, seven different yield categories were established for use within a hypothetical model. These were 15, 12, 10, 8, 6, 4, and 2:1, giving a range between the best and the very poorest land. The use of the high yields of 10 to 15:1, as mentioned by Varro, provide an opportunity to test the agricultural implications of his statements, and enable the calculation of a maximum Roman production figure for the study area. It is also possible to calculate the production of sites within low yielding areas in order to ascertain whether or not it would have been worthwhile carrying out cereal cultivation. We may then gain some idea of the potential economy of certain sites from the South Etruria database – whether likely to have been pastoral or arable, or some other function – complementary to the assessments of the previous chapter. This is approached in Chapter 8.

Hypothetical territories were tested according to this selection of crop yields to see how much grain could have been produced and, as a consequence, how many people different sized estates could theoretically support (Table 7.14). Using the data collected regarding plot size (Chapter 3) seven different plot sizes were used, ranging from the historic *heredium* of 2 *iugera* (0.5ha) up to a 240 *iugera* (60ha) estate. The yields were then converted into their calorific equivalent, the FAO standard of 3,340 calories per kilogram of soft wheat (Aykroyd and Doughty 1970: 18).

Only adult males and females are modelled in this instance, using the range of calorific requirements established in the previous section. A simple fallow of one third was subtracted from these results along with seed at a sowing rate of five *modii*/*iugerum* for the following year. Other fallowing and rotation schemes did exist at this time, but were not used for this model. The additional calories gained from animal products were also not incorporated at this stage.

Table 7.14 Number of adult labourers supported annually per site for hypothetical territories and yields (maximum model assumes borderline malnourishment)

	Plot size (ha)	Total crop in kg	1/3 fallow	Seed	Remaining crop	Calories	Adults supported Min	Max
2 fold return								
200 iugera	50	13500	4500	6750	2250	7515000	5	11
100 iugera	25	6750	2250	3375	1125	3757500	3	5
60 iugera	15	4050	1350	2025	675	2254500	2	3
40 iugera	10	2700	900	1350	450	1503000	1	2
12 iugera	3.14	848	283	405	160	535068	0.4	1
7 iugera	1.75	473	158	236	79	263025	0.2	0.4
2 iugera	0.5	135	45	68	23	75150	0.1	0.1
4 fold return								
200 iugera	50	27000	9000	6750	11250	37575000	27	53
100 iugera	25	13500	4500	3375	5625	18787500	14	26
60 iugera	15	8100	2700	2025	3375	11272500	8	16
40 iugera	10	5400	1800	1350	2250	7515000	5	11
12 iugera	3.14	1696	565	405	725	2422836	2	3
7 iugera	1.75	945	315	236	394	1315125	1	2
2 iugera	0.5	270	90	68	113	375750	0	0.5
6 fold return								
200 iugera	50	40500	13500	6750	20250	67635000	49	95
100 iugera	25	20250	6750	3375	10125	33817500	24	47
60 iugera	15	12150	4050	2025	6075	20290500	15	28
40 iugera	10	8100	2700	1350	4050	13527000	10	19
12 iugera	3.14	2543	848	405	1291	4310604	3	6
7 iugera	1.75	1418	473	236	709	2367225	2	3
2 iugera	0.5	405	135	68	203	676350	0.5	1
8 fold return								
200 iugera	50	54000	18000	6750	29250	97695000	70	137
100 iugera	25	27000	9000	3375	14625	48847500	35	69
60 iugera	15	16200	5400	2025	8775	29308500	21	41
40 iugera	10	10800	3600	1350	5850	19539000	14	27
12 iugera	3.14	3391	1130	405	1856	6198372	4	9
7 iugera	1.75	1890	630	236	1024	3419325	2	5
2 iugera	0.5	540	180	68	293	976950	0.7	1
10 fold return								
200 iugera	50	67500	22500	6750	38250	127755000	92	179
100 iugera	25	33750	11250	3375	19125	63877500	46	90
60 iugera	15	20250	6750	2025	11475	38326500	28	54
40 iugera	10	13500	4500	1350	7650	25551000	18	36
12 iugera	3.14	4239	1413	405	2421	8086140	6	11
7 iugera	1.75	2363	788	236	1339	4471425	3	6
2 iugera	0.5	675	225	68	383	1277550	1	2

Table 7.14 continued

	Plot size (ha)	Total crop in kg	1/3 fallow	Seed	Remaining crop	Calories	Adults supported Min	Max
12 fold return								
200 iugera	50	81000	27000	6750	47250	157815000	114	222
100 iugera	25	40500	13500	3375	23625	78907500	57	111
60 iugera	15	24300	8100	2025	14175	47344500	34	66
40 iugera	10	16200	5400	1350	9450	31563000	23	44
12 iugera	3.14	5087	1696	405	2986	9973908	7	14
7 iugera	1.75	2835	945	236	1654	5523525	4	8
2 iugera	0.5	810	270	68	473	1578150	1	2
15 fold return								
200 iugera	50	101250	33750	6750	60750	202905000	146	285
100 iugera	25	50625	16875	3375	30375	101452500	73	142
60 iugera	15	30375	10125	2025	18225	60871500	44	85
40 iugera	10	20250	6750	1350	12150	40581000	29	57
12 iugera	3.14	6359	2120	405	3834	12805560	9	18
7 iugera	1.75	3544	1181	236	2126	7101675	5	10
2 iugera	0.5	1013	338	68	608	2029050	1	3

The results table shows that, in the case of the historic *heredium* of two *iugera*, the land would have had to have given a yield of over 6:1 to support even one person at a very low nutritional level, let alone an average household. Even at the highest returns of 15:1 only a maximum of three people could be supported, and a household would therefore have had to rely on hired labour or foraging to support them. Likewise, a standard veteran allotment of seven *iugera* would have had to have been well-situated with a good yield of at least 8-10:1 in order to support a household of five people, but a 15:1 yield would have been plenty, supporting between 5-10 people.

It is not being suggested, of course, that the Roman diet consisted entirely of cereals. As stated previously, this diet would have been supplemented to some extent with other foodstuffs such as olives, wine, fruit, meat, and dairy produce, as discussed above. However, other foods were either grown on ones own farm, or bought in exchange for cereals or cash from the sale of cereals. Therefore, in this instance, cereal production alone is used as an index of consumption. Other models will be carried out in Chapter 8.

7.4 Conclusions

Analysis of the available data showed that diet was likely to have been varied, but that the vast majority of calories were likely to have been supplied by wheat. The range of calorific intake was also investigated and a number of models put forward. A range of nutritional requirements was established which took into consideration differences in stature and gender, as well as a range of Body Mass Indexes (from malnourished to healthy). This range also incorporated two different lengths of working day – three and nine hours. It was noted that, whilst the ranges from malnourished to healthy was wide for each model, the contrast between the two model working days was minimal in comparison. As such, both models were combined to give absolute minimum and maximum figures for supported population.

Once established, hypothetical territories were tested with potential wheat production and the number of people supported assessed according to these figures. It is clear from the initial results that the 4:1 yield, so frequently cited as the average Italian yield (see Chapter 6), is not sufficiently productive to support a household without significant recourse to other food sources unless plot sizes were fairly large (over 12 *iugera*). Further analysis in Chapter 8 therefore looks at applying yield data to the study area, and assessing potential production and carrying capacity.

8 YIELDS, SURPLUS AND URBAN DEPENDENCY

Whilst the previous chapter made a preliminary assessment of yields from hypothetical territories, this chapter looks at the potential population of the area as determined firstly by field survey results (Section 8.1), and secondly by carrying capacity (Section 8.2-8.6). A number of models are presented in this chapter, for different types of crops as well as mixed economies. These serve to highlight which sites are most suitable for which agricultural strategies and the maximum production figure they could have produced. This leads on to questions of surplus and urban provision, which are approached at the end of this chapter.

8.1 Regional demography in Roman Italy

It is clear from the demographic studies used in the previous section that there is very little direct evidence to indicate the probable population of the study area. However, the various estimates outlined previously provided an interesting yardstick against which to test the models presented here. Demographic data (such as censuses) as a whole is often problematic and prone to inherent biases. Parkin, for example, argues that ancient sources for demography are,

> *...so plagued with biases and produce such potentially misleading or improbable information that they cannot be considered usable*
>
> Parkin 1992: 58

This argument is also reiterated in a later work (Parkin 1999). However, this scepticism is argued against and, although the drawbacks in such data are noted, the utility of such evidence is defended by other scholars of demography (e.g. Frier 1992; 2001: 145; Lo Cascio 1994: 40).

It has been argued by Morley (1996: 102-3) that the mid-1st century BC to the 2nd century AD was a period of recovery from the Punic wars and increasing prosperity. This recovery has been linked to the growth of Rome and its position as a major market, as well as to the extensive resettlement of military veterans. We could therefore assume that the population dynamics of the study area are linked to the increasing prosperity of the Roman Empire and the emergence of a huge market at Rome. Rome was well connected to its hinterland, of which our study area forms a major part, by a series of transport routes that enabled the long-distance movement of goods from the countryside to the city. This would have necessitated the expansion of activity in this area, and so settlement was bound to increase enormously, in our study area. According to the field survey data settlement more than doubled in this period.

A recent discussion of the relationship between field survey and demography (Lo Cascio 1999) attempted to use a variety of data to determine the probable population, as well as an assessment of the urban-rural split and possible settlement dynamics. Traditional demographic techniques have been based on literary and epigraphic evidence, particularly the census figures. Field survey, however, can provide added insight into the dynamics of settlement. Also, survey data are our only way of detecting regional variations in density as the sources tend to give only overall numbers for the country (Lo Cascio 1999: 161). As a caveat, however, using survey data to form populations is fraught with difficulties. To begin with, distribution maps formed from survey data are merely an unknown proportion of the actual sites that may have existed. General demographic trends may be surmised, but due to the problems of determining the contemporaneity of sites within quite long time periods, anything more detailed is problematic. However, the survey data presented here, although tainted with the same problems, are investigated in such a way as to test demographic models rather than claim absolute truth.

Many Mediterranean areas surveyed have demonstrated densities of around five sites per km^2 (Bintliff 2002: 29). Assuming a basic family unit of around six people this equates to approximately 30 people/km^2. The Tiber Valley field survey results show 1,188 rural sites in the surveyed area of 140,518ha. With a household of six this would equate to a density of only 5 people/km^2, far lower than the other Mediterranean surveys. Firstly, however, this does not take account of larger numbers in villa households. Also, looking more closely at the field survey data, the results show a great diversity of settlement density, not only between regions, but also intra-regionally. This means that any attempt to determine the overall population density of Roman Italy is a rather pointless exercise, given the large expanses of unoccupied land and nucleated settlement around urban centres. What would be more interesting is to look at the differences in population density across a variety of regions and determine the reasons for these differences. Were they to do with distance to markets, proximity to valuable resources, or for some other socio-economic reason? Although an interesting possibility, the realities of combining evidence from a variety of surveys across Italy, or indeed the Mediterranean as a whole, would be problematic, not least due to differences in collection strategy.

Regional settlement density has been investigated by Witcher (2005) who, using the same field survey data as this study, made a preliminary attempt to estimate the Early Imperial population of the *suburbium* of Rome using a 50km catchment area. Using 5-15 people per farm and 15-50 per villa, plus varying populations for nucleated centres, the population was estimated as being between 193,275-644,200 – a density of 35.7-119 people/km^2. He decided on an 'informed estimate' of 60 people/km^2, with 32% in centres and 68% in the countryside (changing to 25% / 75% if Ostia is excluded). Applying the theory that this area was the densest settled in the peninsula, it was argued that the lower population densities of Beloch and Brunt were more likely for the country overall (Witcher 2005: 126-128).

Looking at this same data here, it is an interesting exercise to assume a fixed population for farms and villas in order to investigate regional variation. In this instance, rather than a range, a static household of 6 people per farm and 25 people per villa was assumed. The farm population was considered appropriate as this figure suggests a standard household of two adults, three children and one elderly dependent. Duncan-Jones has argued that a plot of 50 *iugera* would require only four men to work if under grain (Duncan-Jones 1982: 49-50), and so a smaller plot with a mixed economy would be easily cultivated with six, some of whom would have had domestic responsibilities.

The figure for villas was determined from the agronomists who stated numbers for the workforce of a 100 and 240 *iugera* estate. Cato stated that 16 people were required to work a 100 *iugera* vineyard. These were one overseer, one housekeeper, ten labourers, one teamster, one muleteer, one willow-worker, and one swineherd. Equipment included two oxen and two draft-donkeys (Cato *de Agr*. 11). This implies that the cultivation of vines was not the only thing occurring on this estate. The presence of a swineherd on the list indicates some animal-rearing occurring in conjunction with the viticulture, and the oxen and draft donkeys may point to some intercropping of field crops between the vines. Cato's 240 *iugera* oliveyard, on the other hand, required only 13 people. Despite covering a larger acreage this is seemingly a less labour intensive enterprise. The labour force consisted of one overseer, one housekeeper, five labourers, three teamsters, one muleteer, one swineherd, and one shepherd. Equipment included three yoke of oxen, three pack-asses to carry manure, one ass for the mill, and 100 sheep. The presence of sheep and a swineherd imply an element of animal-rearing, whilst the oxen indicate ploughing, which may show that some cultivation of field crops was occurring, either in combination with the olives or separately (White 1988: 234; Duncan-Jones 1982: 37). Columella (*Rust*. 2.12.1-6), however, states that a 200 *iugera* estate may be worked using only two yoke of oxen, two ploughmen and six labourers. This figure of eight men for a 200 *iugera* farm (2.12.7-9) has been suggested by Duncan-Jones (1982: 49-50) to actually represent a workforce of eight per 100 *iugera* (assuming a 50% fallow).

We therefore have a variety of manpower requirements from the sources. Obviously the number of workers required is dependent on the economy followed. However, if we assume that the estates followed the most labour intensive strategy (in this case viticulture) then we may estimate the local consumption at its maximum. If we added potential household staff and the resident elite at any time, then we may increase the villa population from sixteen to around twenty-five.

A selection of surveys from within the study area were used to gain a more accurate picture of any regional variation. These were the Sutri surveys, the southern *ager Faliscus*, the *ager Capenas*, the region of the Cassia-Clodia survey, the *ager Veientanus*, and the area east of the *ager Veientanus* (nos. 2-4 and 10-12 in Figure 8.1).

Figure 8.1 South Etruria surveys used for regional analysis in blue

In the Later Republic these areas had low population densities, rising dramatically in the Early Imperial period (Tables 8.1-2) but still these later results were low when compared to the calculations of population density discussed above.

Table 8.1 Regional distribution of Late Republican farms and villas and potential population

Late Republic	Veii	E. of Veii	Cass_Clod	Capena	Faliscus	Sutri
No. of farms	37	22	7	24	20	10
Population (6 per site)	222	132	42	144	120	60
No. of villas	68	29	20	38	26	13
Population (25 per site)	1700	725	500	950	650	325
Total population	1922	422	242	524	380	190
Area of survey in km^2	118.46	57.41	140.19	247.65	210.28	90.41
Density per km^2	16	7	2	2	2	2

Table 8.2 Regional distribution of Early Imperial farms and villas and potential population

Early Imperial	Veii	E. of Veii	Cass_Clod	Capena	Faliscus	Sutri
No. of farms	147	59	29	80	87	47
Population (6 per site)	882	354	174	480	522	282
No. of villas	158	47	50	93	66	30
Population (25 per site)	3950	1175	1250	2325	1650	750
Total population	4832	1529	1424	2805	2172	1032
Area of survey in km^2	118.46	57.41	140.19	247.65	210.28	90.41
Density per km^2	41	27	10	11	10	11

With the exception of the area of Veii, most of these densities are lower than the previous demographic estimates (up to 64 people/km^2), and not what we would necessarily expect from a well-developed area close to many urban centres, particularly Rome. This technique is therefore not satisfactory for calculating populations from survey data alone, particularly as we are not including any potential urban populations in the study area, which could raise the numbers dramatically.

An alternative method of determining potential population levels is therefore necessary, involving investigation into other contributing factors. Carrying capacity has, in this respect, been touted by demographers as the most realistic way of determining theoretical maximum supported population figures (e.g. Frier 2001: 141). By determining the maximum carrying capacity of the study area, a population figure may be determined against which to test the demographic models discussed above. Each known site may be given a territory and therefore a maximum resource, and the numbers supported by this calculated.

8.2 *Yield maps for the study area*

Creating a map that would identify those areas yielding the most for different types of economy was therefore the next stage of the analysis. Different crops grow better under different circumstances, and this was noted by Virgil.

> *The different crops that different parts of it yield or yield not.*
> *A corn-crop here, grapes there will come the happier issue:*
> *On another soil it is fruit trees, and grass of its own sweet will*
> *Grow green.*
>
> Virgil *Georg.* 1.53-56

These different crop requirements are assessed as far as is possible, and potential yield maps are created based on areas of predicted best suitability, according to the ancient sources and comparative evidence. Although it has been noted previously (Chapter 6) that production was rarely confined to one single crop, many of the models produced here relate to monoculture, particularly of cereals. This is not to say that we are suggesting such a strategy, merely that we are testing the effects of such an economy. We may determine which crops were most suited to which areas and determine how much each could have produced. A model incorporating intercropping is therefore to be carried out.

8.2.1 Modern yields and demographic estimates for Roman period Italy

The first stage of analysis involved the creation of a benchmark against which to test the results of the hypothetical yield maps. In order to produce this upper limit for production figures in the area, modern population and production statistics were assessed.

To calculate modern production a basic model was run. The modern land use map was first reclassified to show only those areas used for cereal production, and then the area calculated. This amounted to nearly 57% of the study area. Added to this is a further 31% of land devoted to complex agriculture. These areas are evident from the modern land use map, and are further illuminated by nineteenth century cadastral maps from the area (Archivio di Stato di Roma 2002). These sources demonstrate the existence of a method of cultivation whereby a variety of different crops are grown on the same plot. These could be any combination of cereals, vines, olives, or other tree and field crops.

Statistics from between 1961 and 1970 (FAOSTAT 2003) gave figures for the amount of land cultivated, yield per hectare, total production and amount of seed in Italy. From this one can estimate that the overall yield for the country ranged between 1,849 and 2,392 kilograms per hectare (Table 8.3). From the statistics derived from these figures below we can see also that the return on seed tended to be between 11 and 14:1, although this does apply to production over the country as a whole and therefore disguises any regional variability.

Table 8.3. Modern agricultural statistics for Italy, 1961-1970 (after FAOSTAT 2003)

Year	Yield kg/ha	Total production in tonnes	Total no. of km^2 cultivated	Sowing rate in kg/ha	Seed return
1961	1,910	8,301,200	43,455	170	11:1
1962	2,085	9,496,900	45,555	171	12:1
1963	1,849	8,126,800	43,944	171	11:1
1964	1,948	8,585,800	44,081	171	11:1
1965	2,280	9,775,900	42,884	172	13:1
1966	2,199	9,399,600	42,741	175	13:1
1967	2,392	9,595,600	40,118	174	14:1
1968	2,256	9,655,400	42,801	175	13:1
1969	2,272	9,584,600	42,179	174	13:1
1970	2,341	9,688,600	41,384	174	13:1
Mean	2,153	9,221,040	4,291,4	173	

The average yield over the decade (2,153kg/ha) was applied to the study area to achieve an absolute maximum output. The digital land use map indicated that there are approximately

78,027ha of arable land and 54,885ha of complex agriculture. Production was calculated on the basis of the average yield multiplied by the area covered. The area of complex agriculture was assumed to produce half the amount of cereals, as wheat would have been sown between rows of vines or olive trees (Chapter 6.1.4), plus the maximum olive yield at 329kg/ha (see Table 6.9, page 265). Overall production for the area was therefore calculated as 227,074 tonnes of wheat plus 18,056 tonnes of olives. This does of course discount the dietary contribution of other crops cultivated or animals reared, which must be taken into account when reviewing the results.

The calorific equivalent of one kilogram of soft wheat is 3,340 calories (Aykroyd and Doughty 1970: 18), whilst the calorific value of a kilogram of olives is approximately 8,878 calories (after Mattingly 1988a: 33-34). The calorific equivalent of this modern yield may therefore be divided by nutritional requirements established in Chapter 7 to demonstrate the number of people supported by this harvest. The requirements used are those used in later models and explained below (Table 8.4).

Table 8.4. Methodology for calculating agricultural production

Total Wheat Yield	227,074 tonnes
Reduction for seed (173 kg/ha)	18,246 tonnes
Reduction for waste and loss (20%)	45,415 tonnes
Total minus losses	163,413,002 tonnes
Calorific equivalent	545799427876 kcal
Total olive yield	18,056 tonnes
Calorific equivalent	160,304,325,549 kcal
Total calories produced	706,103,753,425 kcal
Number of people supported - min	509,355
Number of people supported - max	991,559
Population density per km^2 - min	214
Population density per km^2 - max	417

For comparison, population statistics from the 1940s for the Lazio region, within which our study area falls, show that the population was 2,647,088 in the early 1930s. Not counting the city of Rome itself, this is most dense in the Roman suburbs where there are over 500 people/km^2. This reduces to between 150-200 people/km^2 in the area immediately surrounding this, and then again dramatically drops to between 5-50 people/km^2 in the more distant countryside (Naval Intelligence Division 1945b: 493, fig. 31). This gives an average density of 96 people/km^2, excluding the population and area of Rome itself for the study area. Modern figures from 2001 show Lazio (minus Rome) to have increased to a population density per square kilometre of approximately 161 people/km^2 (ISTAT 2001, tab. 2).

The early 20th century population density of 96 persons/km^2, or even the 161 people/km^2 from 2001 when compared to the potential supported population of 214-417 people/km^2 modelled above, shows that the area was capable of generating a large surplus, even when a percentage of the cereal crop is subtracted for seed or losses. Of course, much of this production either goes to feed the towns in the area including Rome, with a modern population of over 2.6 million, as well as exports abroad. This population density may therefore serve as an absolute maximum figure for wheat production and the supported resident population, against which to test our models. Likewise, the yield of 2,153kg/ha is likely to represent a maximum, given the improved technology since the Roman period. It is therefore extremely unlikely that modelled yields for the Roman period will be anywhere near those of the modern period.

Demographic studies of ancient Italy have produced a range of suggested population densities for the whole country. These range from the figures given by Beloch, Brunt, and Hopkins of around 20-28 people/km^2 (Beloch 1886: chap. 8; in Lo Cascio 1999: 162; Brunt 1971a: 124ff;

Hopkins 1978: 7), to Frank and Lo Cascio's higher estimates of 50-64 people/km^2 (Frank 1924: 340; Lo Cascio 1999: 166ff). It may be noted that these figures are vastly lower than the modern statistics, which is perhaps unsurprising. However, as well as the likely overall population increase, these ancient figures relate to an average of the country as a whole. It may be assumed, consequently, 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 modern population density of Lazio shown above demonstrates a diminishing population density the further one goes from the capital.

Within the study area, the survey sites have been interpreted to illustrate the rise in population in this area from the Late Republic to the Early Empire, the latter phase being the period of maximum density of settlement. From the 1st century BC, and particularly during the 1st century AD, there was a great increase in the larger sites and in the quality of finds. Rather than displacing the poorer settlements, however, these villas were in fact part of the intensification of settlement in this area, with their numbers decreasing with distance from Rome (Morley 1996: 100). In some areas, particular Sutri, the increase in sites has been attributed to a kind of "*agricultural colonization*", whereby the settlers expanded gradually into the newly deforested areas of the Ciminian forest (Witcher, discussion in van Leusen 2002: 129; Duncan 1958: 95). Agricultural intensification has been attributed partly to the increasing population, but also due to the desire of farmers to emulate the elite. Acquiring luxury foods or embellishing farms required the production of a surplus for exchange (Dyson 1992: 77).

Therefore, we may assume that the population dynamics of the study area are linked to the increasing prosperity of the Roman Empire and the emergence of a huge market at Rome. This was well connected to its hinterland, of which our study area forms a major part, by a series of transport routes that enabled the long-distance movement of goods from the countryside to the city. This would have brought about the expansion of activity in this area, and so settlement was bound to increase enormously in this period; in our study area more than doubling according to the survey data.

A recent discussion of the relationship between field survey and demography (Lo Cascio 1999) attempted to use a variety of data to determine the probable population, as well as an assessment of the urban-rural split and possible settlement dynamics. Traditional demographic techniques have been based on literary and epigraphic evidence, particularly the census figures. Field survey, however, has contributed greatly to this area, giving us added insight into the dynamics of settlement, and can be a useful yardstick against which to test the traditional sources. Also, survey data are our only way of detecting regional variations in density as the sources tend to give only overall numbers for the country (Lo Cascio 1999: 161). As a caveat, however, using survey data to form populations is fraught with difficulties. To begin with, distribution maps formed from survey data are merely "*'palimpsests' of a reality which has now disappeared*" (Cambi 1999: 115). The data must therefore be treated with caution. General demographic trends may be surmised, but due to the problems of determining the contemporaneity of sites within quite long time periods, anything more detailed is problematic. However, the survey data presented here, although tainted with the same problems, are investigated in such a way as to test demographic models rather than claim absolute truth. The problems of recovery may be negated, however, by doing similar analysis on different numbers of rural sites using random samples to test the effects of different population densities (see analysis in Section 8.4).

Many Mediterranean areas surveyed have demonstrated densities of around five sites per km^2 (Bintliff 2002: 29). Assuming a basic family unit of around six people this equates to approximately 30 people/km^2. Many of these sites will have been of a larger magnitude than a basic subsistence unit and were situated in rich farmland. We may therefore assume that this figure is a minimum potential density for the areas in question. The potential range is therefore from 30 people/km^2 up to an absolute maximum of 412 (as the modelled maximum carrying capacity of the area), though it is more likely to be in the region of 30-161 people/km^2 (using the modern population density).

8.2.2 Creating the arable yield map

In order to apply the data collected on yields to the study area, it was first necessary to create a basic yield map showing the areas predicted as suitable for cereal production. Using the productive potential map created in Chapter 5, it was possible to reclassify this as a "yield map", with each area coded according to the weight (in kg) per hectare of wheat produced for that particular yield. To illustrate, the suitability categories were stretched between the minimum and maximum yield in kilograms per hectare. All areas showing the highest suitability for arable agriculture (class 255) were given the highest yield category of 15:1, or 2,025kg/ha. This was assuming a five *modii* per *iugerum* sowing rate. The maximum figure of 15:1 was chosen, as it was the yield given by Varro for all of Etruria. Whether or not this is an exaggeration is therefore irrelevant here, as we are only interested in establishing the likely ancient maximum production. Other yield maps reflecting different yields from the sources are created later.

This type of evaluation is, in essence, qualitative. The application of potential yield to suitability for crop is based on the basic assumption of best suitability = most productive, worst = least productive. This means that such models cannot hope to be exact assessments of agricultural production, particularly as they are based on historical accounts. They do, however, demonstrate the effects on the same landscape of differing yields, which is of particular importance when looking at bad years and their effects.

A new suitability map was created based purely on the environmental rather than social factors, in the same way as in Chapter 5 using equal weighting for all factors. Factors used were therefore fertility, slope, and aspect, whilst constraints were wheat altitude limit and lakes. Once created, the image was scaled to reflect a maximum of 15:1 yield (2,025kgs/ha)

Once the yield map (Figure 8.2) was complete, it was possible to extract information on the area covered by each yield category and therefore derive the potential production of the entire study area. The total output of wheat in kilograms for the entire area amounted to 318,380 tonnes of wheat over an area of approximately 241,993 hectares (slightly less than the modern calculation as the study area lacks a DEM for part of the area), giving an average yield of 1,315kg/ha.

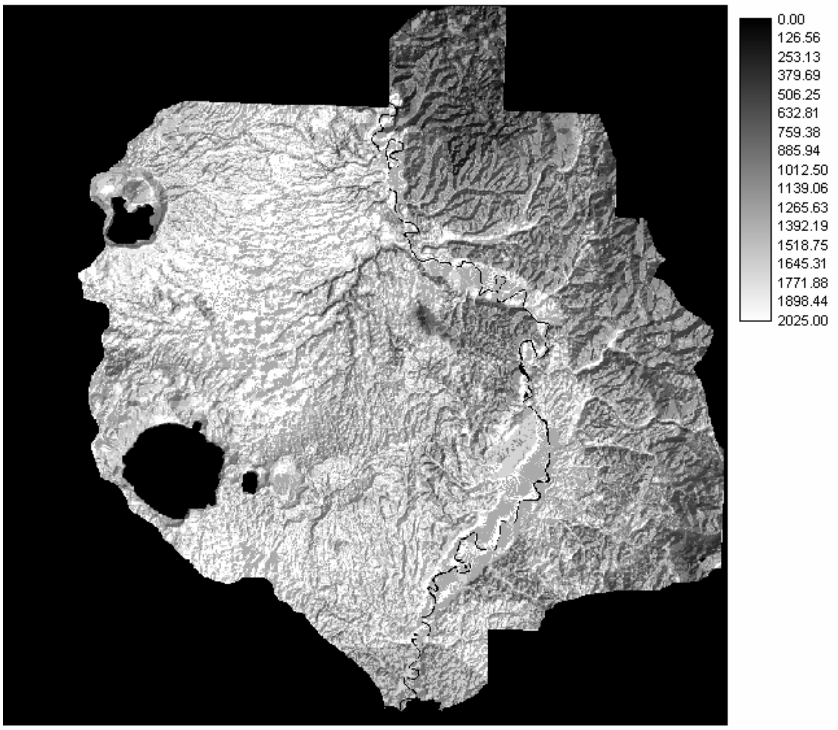


Figure 8.2 Yield map for arable production

A portion of this would have to be conserved for sowing the next year's crop. As a sowing rate of 5 *modii* per *iugerum* was being used, it was decided to buffer this amount to allow for losses due to factors such as infestations of stored grain or other factors affecting storage and processing. The FAO has recommended a figure of 10% for wastage/losses in food preparation when unknown (1973b). However, we know from comparative evidence that losses could be enormous (see Chapter 6.2.3), depending on the type of problem. An extra 10% was deducted to account for pests, and another 10% on top of this for losses during processing. It has been noted that, even in third world countries where food shortages are common, it is still considered necessary to mill off 10% of the wheat which is considered unfit for human consumption (Clark and Haswell 1970: 57). This meant a total loss of around 30% of the crop.

After subtracting these factors from the crop, the yield of the total study area was calculated assuming continual cropping of the entire area. The nutritional equivalent of the wheat yield was established and divided by the requirement of an adult agricultural labourer, as determined previously. This requirement was between 712,115-1,386,270 calories. The total number of adults supported for the study area was therefore between 458,251-892,074 people with a supported population density of 189-369 people/km^2 (compared to the modern modelled density of 214-417 people/km^2, Section 8.1.1). This high density, however, assumes that the *entire* study area – approximately 2.4% of Italy's entire land mass – was given over to arable cultivation. This is extremely unlikely, not least because of the presence of urban areas, pastoral activities, woodland, industrial sites, other crops, as well as problems such as the exhaustion of the soil. It does, however, provide us with a template, against which to model a variety of exploited territories.

The diversity of agricultural practice means that a range of fallowing systems or rotations must be applied to the model in order to gauge the different effects different techniques would have on production. The four ranges chosen were a) continual cropping, b) ¼ fallow and ¾ cropped, c) ½ fallow and d) ¾ fallow and ¼ cropped. Strategy B allows concession to be made for diversity in practice, giving three-quarters of the area allowance for calories gained by either combination cropping or a rotation of some sort. This, as expected, reduced the population supported quite considerably (Table 8.5).

Other historical yields from the sources were next tested in this fashion. Wheat yields of 4:1 (540kg/ha), given by Columella for the whole of Italy, and 8:1 (1,080kg/ha) were also modelled (Table 8.6).

Table 8.5. Results of arable model #1

Model	People supported		Population density per km^2	
	Minimum	Maximum	Minimum	Maximum
Continual cropping	458,251	892,074	189	369
¼ fallow and ¾ cropped	343,688	669,055	142	276
½ fallow	238,964	465,190	99	192
¾ fallow and ¼ cropped	114,563	223,018	47	92

Table 8.6. Results of arable models #2 and #3, sowing rate 5 modii/iugerum

Yield	Model	People supported		Population density per km^2	
		Minimum	Maximum	Minimum	Maximum
8:1	Continual cropping	286,261	557,262	118	230
	¼ fallow and ¾ cropped	214,695	417,946	89	173
	½ fallow	143,145	278,660	59	115
	¾ fallow and ¼ cropped	71,565	139,315	30	58
4:1	Continual cropping	143,177	278,721	59	115
	¼ fallow and ¾ cropped	107,383	209,041	44	86
	½ fallow	71,588	139,361	30	58
	¾ fallow and ¼ cropped	35,794	69,680	15	29

Results for the 8:1 yield gave a range of 118-230 people/km^2. Despite the relatively low yields this is still a reasonable number to be supported, higher than many postulated Roman population densities. However, once fallow was subtracted this reduced to a minimum range of 30-58 people/km^2. The 4:1 yield resulted in even lower figures. The population supported amounted to a minimum density of 15-29 people/km^2. These lower ranges do not really give us the impression of a densely populated landscape, such as has been described in the sources and is particularly low considering the area's proximity to Rome, and the attraction of the capital.

8.2.3 An alternative yield map

Obviously the more one sows the more one reaps, and so a maximum sowing amount of ten *modii* per *iugerum* was applied to the original yield map, thereby raising overall yields per hectare. To illustrate, a 15:1 would have produced 2,025kg/ha with a five *modii* per *iugerum* sowing rate. Raising the sowing rate to ten *modii*, means a yield of 15:1 would produce 4,050kg/ha. This will provide an absolute maximum production figure for the study area. The flip side of this argument is that, although it produces higher yields, it also requires more seed to be deducted. The remaining yield maps (8:1 and 4:1) were also calculated in the same way and the results are outlined below (Table 8.7).

It must be remembered, however, that it is extremely unlikely that the entire area would have been used for arable agriculture. Sites such as urban centres, industrial sites such as kilns, sanctuaries, and woodland, are all known to have existed in this area. What we have done here, therefore, is to gauge the absolute maximum potential for arable agriculture in this area. This caveat makes it all the more important that the 4:1 yields fail to produce enough wheat to cover even seed when fallowed. It is clear then that the 4:1 yield could not have been the norm in the study area, and that either higher wheat yields would have been expected, or that less productive areas would have been given over to alternative crops. The next stage is therefore to carry out the same procedure for different economies, and then to look at the potential of specific sites known from the database.

Table 8.7. Summary of total area models

Yield	Model	5 modii / iugerum Population density per km² Minimum	Minimum	10 modii / iugerum Population density per km² Maximum	Maximum
15:1	Continual cropping	189	369	379	737
	¼ fallow and ¾ cropped	142	276	284	553
	½ fallow	99	192	197	384
	¾ fallow and ¼ cropped	47	92	95	184
8:1	Continual cropping	118	230	236	460
	¼ fallow and ¾ cropped	89	173	177	345
	½ fallow	59	115	118	230
	¾ fallow and ¼ cropped	30	58	59	115
4:1	Continual cropping	59	115	237	461
	¼ fallow and ¾ cropped	44	86	178	346
	½ fallow	30	58	118	230
	¾ fallow and ¼ cropped	15	29	59	115

8.3 Applying territories to the yield maps

We have already stated that, by assuming total coverage in the calculations above, we do not take account of either individual site territories or mixed economic strategies. To approach the first of these problems, the territories derived from the ancient sources in Chapter 3 were applied to the production maps. These sizes were farms of 2, 5, 12, 28 and 40 *iugera*, and larger villas of 100 and 240 *iugera*. Buffers were constructed around the known Early Imperial sites from the database, and then overlaid onto the yield map. This excluded all data outside of these territory buffers. The total number of kilograms produced was calculated and the same calculations for the analysis of the yields above were used, incorporating reductions for seed and other losses. Again, a range of figures was produced according to the different fallowing regimes. This was only done for the 15:1 yield to gauge the maximum output (Table 8.8).

Table 8.8 Summary of all territory models using the 15:1 yield and 5 modii / iugerum sowing rate

Territory	Model	People per unit	
		Minimum	Maximum
2 iugera farms	Continual cropping	1	2
	¼ fallow and ¾ cropped	1	2
	½ fallow	1	1
	¾ fallow and ¼ cropped	0	1
5 iugera farms	Continual cropping	3	6
	¼ fallow and ¾ cropped	2	5
	½ fallow	2	3
	¾ fallow and ¼ cropped	1	2
12 iugera farms	Continual cropping	8	15
	¼ fallow and ¾ cropped	6	11
	½ fallow	4	8
	¾ fallow and ¼ cropped	2	4
28 iugera farms	Continual cropping	15	29
	¼ fallow and ¾ cropped	11	22
	½ fallow	8	15
	¾ fallow and ¼ cropped	4	7
40 iugera farms	Continual cropping	21	42
	¼ fallow and ¾ cropped	16	31
	½ fallow	11	22
	¾ fallow and ¼ cropped	5	10
100 iugera villas	Continual cropping	50	98
	¼ fallow and ¾ cropped	38	73
	½ fallow	26	51
	¾ fallow and ¼ cropped	13	24
240 iugera villas	Continual cropping	101	197
	¼ fallow and ¾ cropped	76	147
	½ fallow	53	103
	¾ fallow and ¼ cropped	25	49

These results show that the very small units were unable to support a household, even if achieving a 15:1 yield. The minimum effective plot size according to the model was therefore between 5 and 12 *iugera*. This leaves no buffer for storage or bad harvests, however, but we are not taking account of the possibility that farmers with small plots were more likely to plant a variety of crops, and also often hired themselves out as seasonal labourers for larger enterprises. This could therefore supplement the shortfall from their own crop, and feed the household.

8.3.1 12 and 100 *iugera* model

It was decided on the basis of both the ancient sources, and the distribution of sites in the area, that the results from 12 *iugera* farms and 100 *iugera* villas should be combined to give a total arable production figure for the area. This was done using both the five and ten *modii* per *iugerum* sowing ratio (Table 8.9). These results show that, depending on the yield and fallowing regime, the study area could support a maximum of 60 people per square kilometre on arable production alone, reducing to 8-45 if fallowed, depending on the regime.

In comparison with the demographic estimates, these overall results are low, as only the highest yielding categories reach such figures (Figure 8.3). For example, Lo Cascio's estimate of 64 people/km^2 (for all citizens in AD 14), Frank's figure of 57 (including slaves), Brunt's estimate of 31 (4.5 million plus 3 million slaves), and Hopkins' 24 people/km^2 (4 million plus 2 million slaves) (see Section 8.1.1). This problem is exacerbated when we realise that these estimates are generally applied as national averages. Italy contains many areas of low population density, such as the less habitable mountainous regions. This would mean that more urbanised areas, especially those near Rome, were likely to have been higher than the average. Ultimately, this means that the densities calculated here for the study area are much lower than we would expect for a region in such close proximity to the capital.

Table 8.9. Summary of wheat monoculture model results

Mod/iug	Yield	Model	People per farm		People per villa		Population density per km^2	
			min	max	min	max	min	max
10	15:1	Continual cropping	17	32	109	212	31	60
		¼ fallow	12	24	82	159	23	45
		½ fallow	8	16	55	108	16	31
		¾ fallow	4	8	27	53	8	15
5	15:1	Continual cropping	8	15	50	98	15	30
		¼ fallow	6	11	38	73	11	22
		½ fallow	4	8	26	51	8	15
		¾ fallow	2	4	13	24	4	7
10	8:1	Continual cropping	8	16	54	106	14	27
		¼ fallow	6	12	41	79	11	21
		½ fallow	4	8	28	55	8	15
		¾ fallow	2	4	14	26	4	7
5	8:1	Continual cropping	4	7	23	45	7	14
		¼ fallow	3	5	17	34	5	10
		½ fallow	2	4	13	24	4	7
		¾ fallow	1	2	6	11	2	3
10	4:1	Continual cropping	4	7	23	45	7	14
		¼ fallow	3	5	17	34	5	10
		½ fallow	2	4	13	24	4	7
		¾ fallow	1	2	6	11	2	3
5	4:1	Continual cropping	1	3	7	15	2	5
		¼ fallow	1	2	6	11	2	3
		½ fallow	1	2	5	9	1	3
		¾ fallow	0	1	2	4	1	1

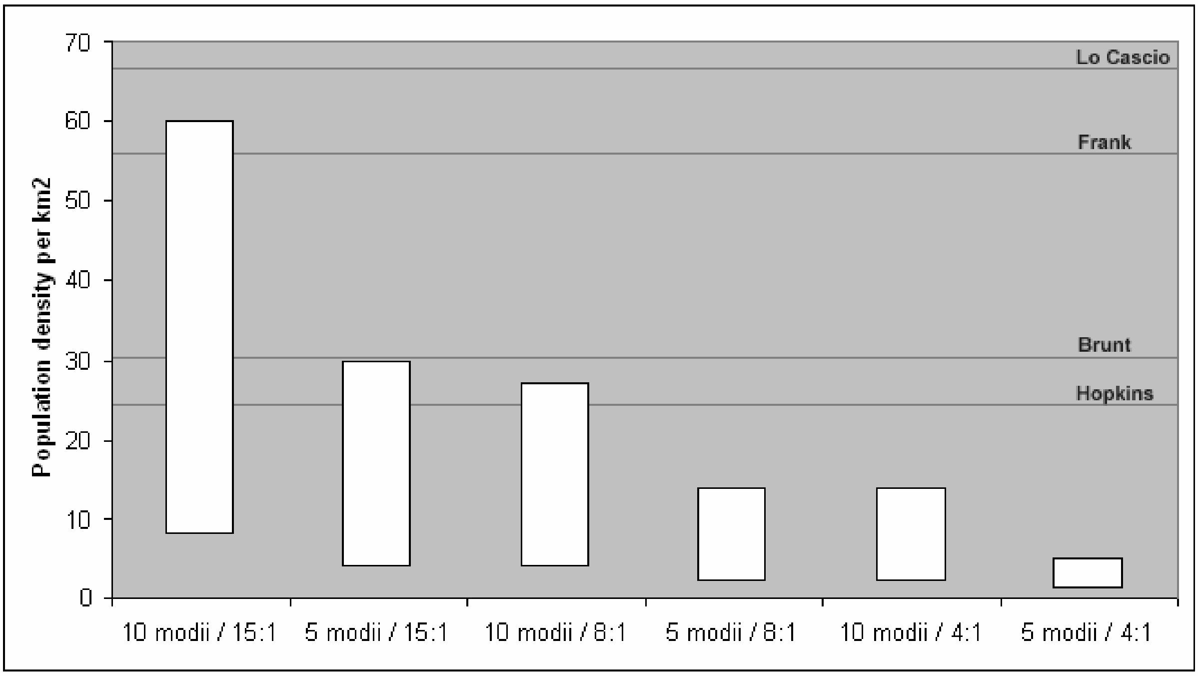


Figure 8.3 Comparison of wheat monoculture yield models with previous demographic estimates (based on total populations including slaves)

The results of these models have been surprising given that we have been dealing primarily with maximum figures. The most important result was that the 4:1 yield of Columella was shown to have been completely inadequate for the area in question within the context of this model, and could only support between 0-3 people per farm at the typical sowing rate of 5 *modii* per *iugerum*. It must also be remembered at this stage that the upper limit for population is based on levels of malnourishment. The yields of 8:1 with maximum sowing rate and yields above this achieved population densities to the levels postulated by Brunt and Hopkins. However, in order to maintain population densities of up to 64 people/km^2 (the Lo Cascio model), the area would have had to have been either much more densely settled than the field survey data suggests, more fertile than the agronomists state, or planted to produce more calories per unit area, probably incorporating animal husbandry.

8.3.2 Incorporating olive production

The process for incorporating olive production was straightforward: all sites were assumed to have practised intercropping and, as such, the yield maps were altered to reflect this. The highest cereal yield was chosen to produce the maximum production model. The arable yield map, at 15:1 with a 10 *modii* / *iugerum* sowing rate, was halved in kilogram production per hectare (White 1970a: 49), and the amount of seed required was also halved, as large areas would not have been cultivated with cereals.

A new suitability map was created for olives in the same way as the arable map (Section 8.1.2), based purely on the environmental rather than social factors, using equal weighting for all factors. The yields for oleoculture used were derived from the intercultivated olive yields from Chapter 6.1.4 (99-329kg/ha). If we take this range to reflect two years' crop (due to the biennial nature of olive yields), the maximum yield used was 214kg/ha and the suitability map classified to reflect this.

In theory this type of cultivation strategy is supposed to increase the unit production overall, even though each crop has an individually lower yield (Gallant 1991: 39-40; Osborne 1987). However, results actually showed slightly less overall production, with a maximum range of between 21-41 people supported per square kilometre, comparable to the 23-45 people for the 15:1 yield with ¼ fallow (Table 8.10). This may indicate that olive yields may actually have been rather higher than postulated here.

Table 8.10. Comparison of monoculture and polyculture, 15:1 models for 12 iugera farms and 100 iugera villas

Mod/iug	Yield	Model	Fallowing	People per farm		People per villa		Population density per km²	
				min	max	min	max	min	max
10	15:1	Cereal monoculture	Continual cropping	17	32	109	212	31	60
			¼ fallow	12	24	82	159	23	45
			½ fallow	8	16	55	108	16	31
			¾ fallow	4	8	27	53	8	15
10	15:1 halved	Intercropped arable and olive	Continual cropping	10	19	62	120	21	41
			¼ fallow	8	15	51	99	17	34
			½ fallow	6	13	42	83	14	27
			¾ fallow	4	9	30	58	10	19
5	15:1	Cereal monoculture	Continual cropping	8	15	50	98	15	30
			¼ fallow	6	11	38	73	11	22
			½ fallow	4	8	26	51	8	15
			¾ fallow	2	4	13	24	4	7
5	15:1 halved	Intercropped arable and olive	Continual cropping	6	12	40	79	13	26
			¼ fallow	5	10	35	68	12	23
			½ fallow	5	9	31	60	10	19
			¾ fallow	4	7	25	48	8	15

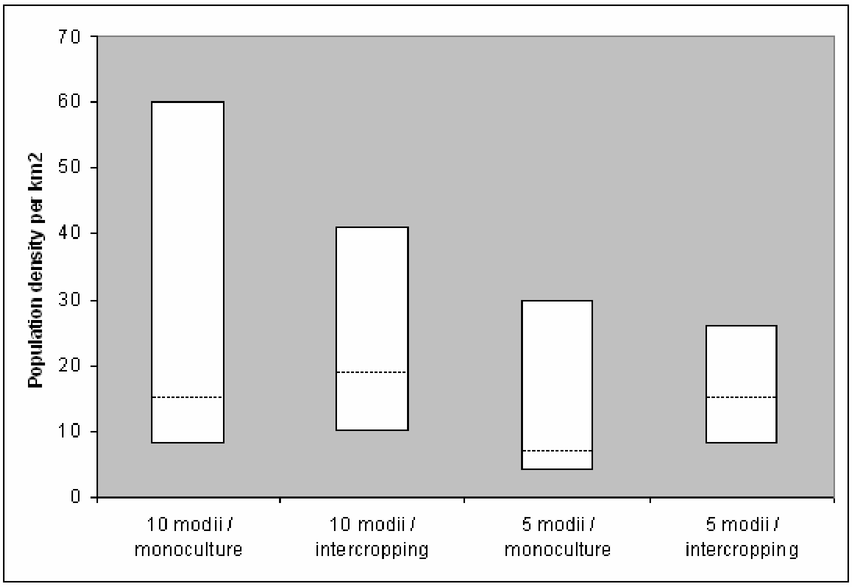


Figure 8.4 Comparison of monoculture and intercropping models for 15:1 yields (dotted line shows upper limit of ¾ fallow model)

However, what this model *does* do is to demonstrate that using a solely arable crop for modelling does not in this instance produce a startlingly different result for overall production. One factor that must be noted however, is that whilst the monoculture models produce higher maximum figures for production, the minimum figures are lower than the intercropping model, and this can be seen clearly in Figure 8.4. This could have implications for bad year strategies.

Comparing the three-quarter-fallowed models (Figure 8.4), however, the highest cereal yields supported 8-15 people/km^2, whilst the fallowed intercropping model supported a higher number of 10-19. Only this high-fallow model agrees with the assumption that intercropping in some circumstances can produce slightly higher yields per unit area.

This idea of increased production was also supported when carrying out models on lower-yielding cereal models (Table 8.9). The olive crop was kept static as this already reflected a lower yield for intercropped yields, and lower cereal yields were then modelled in the same way using the lower 5 *modii* sowing rate. The results showed that even with cereal yields as low as 4:1 (i.e. a yield of 8:1 halved), units could still support a fair number of people with the combination of crops produced (Table 8.11). These figures demonstrate the difference that polyculture would have made on the subsistence of the small farmer (see especially Figure 8.5 for differences between ¾ fallow models).

Table 8.11. Comparison of monoculture and polyculture 8:1 models for 12 iugera farms and 100 iugera villas

Sowing rate mod/iug	Yield	Model	Fallowing	People per farm		People per villa		Population density per km^2	
				min	max	min	max	min	max
10	8:1	Cereal monoculture	Continual cropping	8	16	54	106	14	27
			¼ fallow	6	12	41	79	11	21
			½ fallow	4	8	28	55	8	15
			¾ fallow	2	4	14	26	4	7
10	8:1	Intercropped arable and olive	Continual cropping	6	11	34	67	13	25
			¼ fallow	5	9	31	59	11	22
			½ fallow	4	9	29	56	10	19
			¾ fallow	3	7	23	45	8	15
5	8:1	Cereal monoculture	Continual cropping	4	7	23	45	7	14
			¼ fallow	3	5	17	34	5	10
			½ fallow	2	4	13	24	4	7
			¾ fallow	1	2	6	11	2	3
5	8:1	Intercropped arable and olive	Continual cropping	4	8	27	52	9	18
			¼ fallow	4	7	25	49	8	16
			½ fallow	4	7	24	47	8	15
			¾ fallow	3	6	21	41	7	13

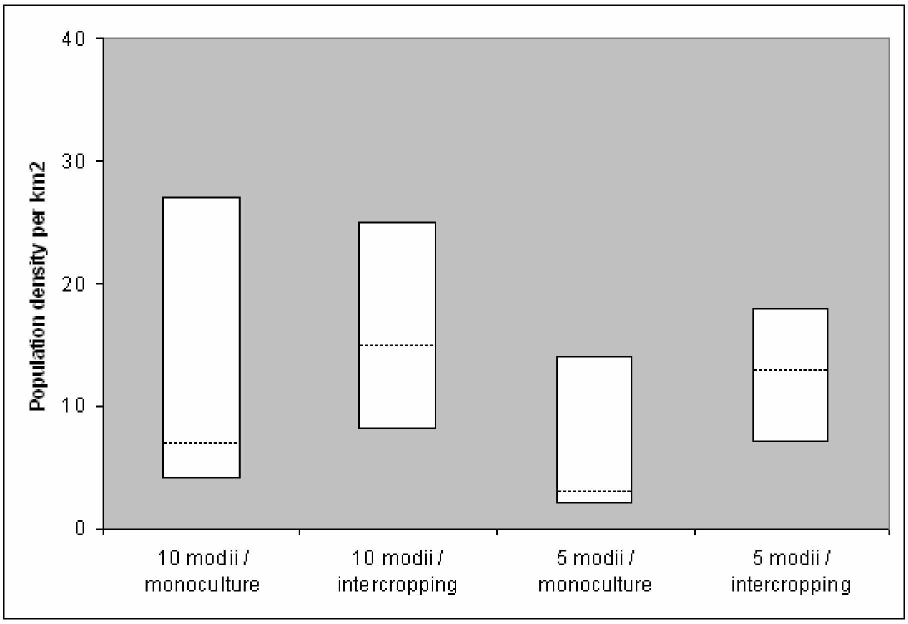


Figure 8.5 Comparison of monoculture and intercropping models for 8:1 yields (dotted line shows upper limit of ¾ fallow model)

The results of further analysis showed, however, that very low cereal yields of 2:1 were uneconomic if cultivated in combination with olives (i.e. 4:1 yield halved). The losses to seed and up to 30% during processing outnumbered the gains, and meant that farmers would have relied solely on the olive harvest. Even increasing the sowing rate to 10 *modii* gained an almost identical harvest due to the amount of seed needed for the next sowing. These results however, relate to farms and villas processed together. Analysing them separately shows that farms could actually support between 3-6 people per site (higher than the 8:1 and 4:1 monoculture models), and it was only the villa sites that were uneconomic in this instance at this yield level. The villas supported 19-39 people per site on the olive crop alone (Table 8.10). This could indicate that these sites were either dedicated to other economies, or had higher grain yields than 4:1.

This model has been extremely important as it has shown that, contrary to the cereal monoculture model from the previous section, by incorporating intercropping the 4:1 cereal yields (i.e. 8:1 halved) and even 2:1 yields (4:1 halved for farms only) were not as inadequate a harvest as previously surmised.

I have considered the figures using the ¼ fallow to be the most reflective of likely production. This is because, even though more extreme fallowing was known to have taken place (often ½-¾), the practice of rotations, and sowing legumes in particular, would have meant that an alternative food source was available to the farmer. If the legumes were used as green manure rather than consumed then this would have meant higher yields due to the improved soil. One-quarter fallowing was therefore thought to encompass such eventualities (Table 8.12).

Table 8.12 Comparison of one quarter-fallow models

Sowing rate mod/iug	Yield	Model	People per farm		People per villa		Population density per km^2	
			min	max	min	max	min	max
10	15:1	Cereal monoculture	12	24	82	159	23	45
10	15:1 halved	Intercropped arable and olive	9	17	57	111	17	34
5	15:1	Cereal monoculture	6	11	38	73	11	22
10	8:1	Cereal monoculture	6	12	41	79	11	21
5	8:1 halved	Intercropped arable and olive	4	7	25	49	8	16
10	4:1 halved	Intercropped arable and olive	3	6	19	37	8	15
5	4:1 halved	Intercropped arable and olive	3	6	19	37	7	13
5	8:1	Cereal monoculture	3	5	17	34	5	10
10	4:1	Cereal monoculture	3	5	17	34	5	10
5	4:1	Cereal monoculture	1	2	6	11	2	3

This comparison (Figure 8.6) shows that, unsurprisingly, the highest yielding model was the 15:1 monoculture yield with a very high sowing rate. The next most productive was the 15:1 (halved) wheat plus olives. This showed that despite a reduction in yield by half, the addition of an olive crop enhanced production. The lowest yielding models were the low yields of cereal monoculture, the worst being 4:1. It was noted that even the 2:1 intercropping yield (4:1 halved) was much more productive than some monoculture models due to the olive crop, but it must be remembered the cereals were uneconomic for villas only and not farms in this case.

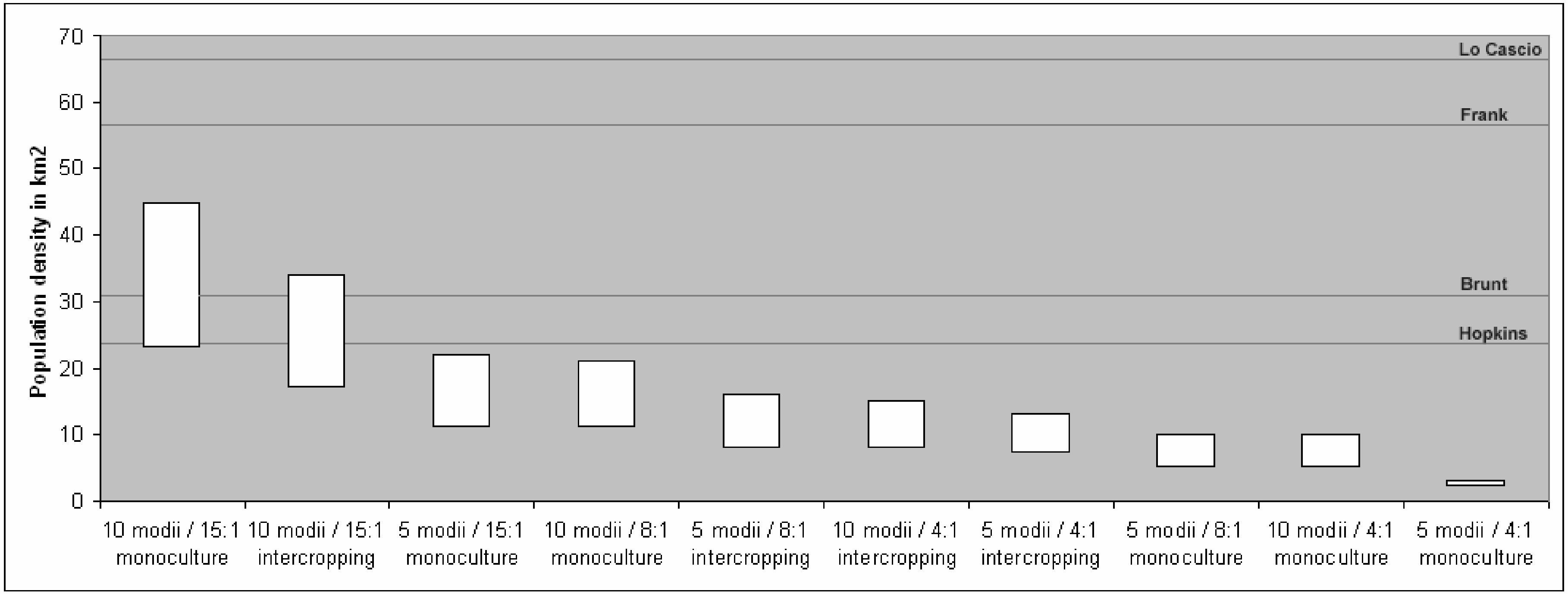


Figure 8.6 Comparison of monoculture and intercropping models for all yields with one-quarter fallowing regime

8.3.3 Incorporating viticulture

The process for incorporating wine production was done in the same way as for olives: all sites were assumed to have practised intercropping and the yield maps were altered to reflect this. The arable yield maps were halved in kilogram production per hectare (White 1970a: 49), and the amount of seed required was also halved. As the modelling of variable wine production was impossible due to the evidence available (Chapter 5.5), two static production figures were used – those for Seneca's vineyards (16,768 litres/ha; Pliny *NH* 14.4.42) and that for "*the very worst of vineyards*" (2,096 litres/ha; Columella *Rust*. 3.3.10).

Table 8.13 assumes only half the farm or villa territory was used, that one litre of wine equalled 710 calories, and that wine consumption was at 350-500 calories per day (cf. Jongman 1988: 79-80). Comparing these results to Witcher's postulated population of 193,275-644,200 for the whole of the Roman *suburbium* (Section 8.1), wine production from this region could have supported a substantial percentage of the larger regional population, and even the very lowest figure (73,106 people) constituted 11-38%.

Table 8.13 Intercultivated wine production in the study area

		Litres per unit	Total production	Calories	People supported
Seneca's vineyards	Farms	25,154	13,457,558	9,554,866,167	52,355 - 74,793
	Villas	209,608	136,873,837	97,180,424,108	532,495 - 760,708
	TOTAL	234,762	150,331,395	106,735,290,275	584,851 - 835,501
The very worst of vineyards	Farms	3,144	1,682,195	1,194,358,271	6,544 - 9,349
	Villas	26,201	17,109,230	12,147,553,014	66,562 - 95,088
	TOTAL	29,345	18,791,424	13,341,911,284	73,106 - 104,438

Incorporating wine into a more complex model, it was decided to produce a model for wine, olives and cereals. Wheat yields were halved as before, and intercultivated olive yields were also halved to account for the remaining land being cultivated with vines (Figure 8.7).

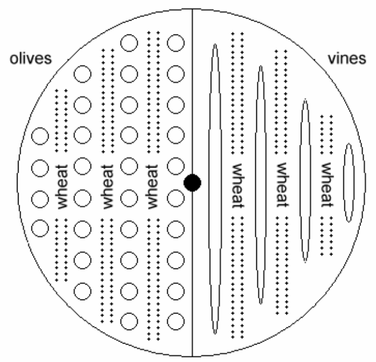


Figure 8.7 Schematic diagram of intercultivation strategy involving olives and vines

Table 8.14. Comparison of previous intercropping model and that using vines, 15:1 models for 12 iugera farms and 100 iugera villas

Mod/iug	Yield	Model	Fallowing	People per farm		People per villa		Population density per km^2	
				min	max	min	max	min	max
10	15:1 halved	Intercropped arable and olive	Continual cropping	10	19	62	120	21	41
			¼ fallow	8	15	51	99	17	34
			½ fallow	6	13	42	83	14	27
			¾ fallow	4	9	30	58	10	19
10	15:1 halved	Intercropped arable, olive and vine	Continual cropping	9	18	59	114	20 (34)	39 (66)
			¼ fallow	7	14	48	93	16 (30)	32 (59)
			½ fallow	6	11	40	77	13 (27)	25 (52)
			¾ fallow	4	8	27	52	9 (23)	17 (44)
5	15:1 halved	Intercropped arable and olive	Continual cropping	6	12	40	79	13	26
			¼ fallow	5	10	35	68	12	23
			½ fallow	5	9	31	60	10	19
			¾ fallow	4	7	25	48	8	15
5	15:1 halved	Intercropped arable, olive and vine	Continual cropping	5	9	29	57	11 (25)	22 (49)
			¼ fallow	4	8	26	51	10 (24)	19 (46)
			½ fallow	4	7	25	48	8 (22)	16 (44)
			¾ fallow	3	5	20	38	7 (20)	13 (40)

*Figures in brackets indicate supported population density using the higher wine yield

Production figures were expected to be lower, as the calorific content of vines produced per hectare is lower than that of olives in this model. However, the higher wine production figure produced higher density figures, and showed that this type of intercultivation strategy could provide more calories if wine yields were good (Table 8.14 and Figure 8.8). Figure 8.8 shows the significantly higher population density achieved when the higher wine yields were used.

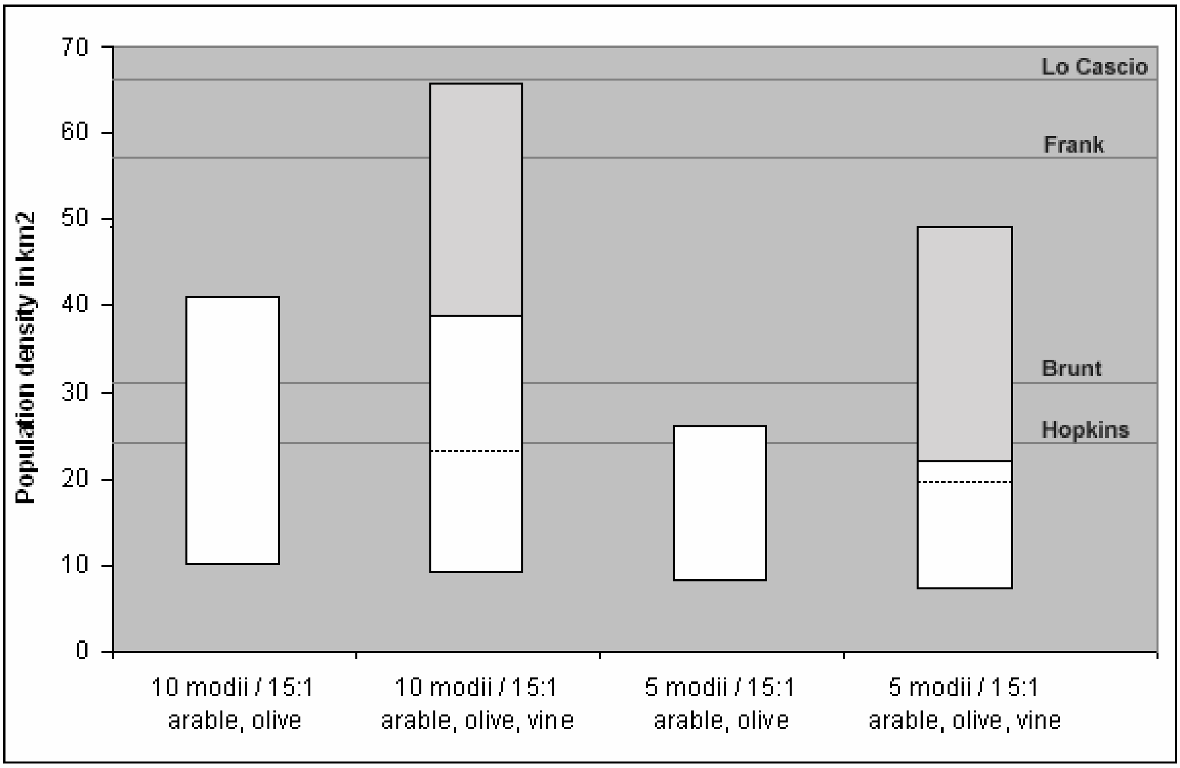


Figure 8.8 Comparison of intercropping models for 15:1 yields (grey bars and dotted line show range of higher wine yields)

8.3.4 The effect of animal husbandry

It is possible to incorporate a rough model of animal husbandry in the area, based upon the models of Delano Smith (1979: 219) outlined in Chapter Six. Delano Smith outlined six different systems of farming, in which animals mostly play a role (1979: 227-229, fig. 30), but only two of these were selected to add to the existing agricultural model. These are:

- Peasants with some land (polyculture), 1-2 pigs, a small flock (1/2 dozen sheep) and 1-2 goats.
- Rich peasants with modest amount of farmed land, a large flock/herd (50-100 sheep/cattle)

The annual calories contributed by each of these animals are outlined in Table 8.15 below. Cattle were not used as, although often present as traction, they were mostly slaughtered at the end of their working life, and would not have contributed regularly to the diet. For the larger estate, a couple of pigs and goats were added to the outline as "*who … cultivates a farm without keeping swine?*" (Varro *Rust*. 2.4.3). Varro goes on to describe pig herds of around 100-150 (*Rust*. 2.4.22), but the estates of the study area lack the amount of land needed to rear pigs at this scale alongside arable and olive cultivation. For this reason, the same number of pigs and goats as the farm was used alongside a larger sheep herd. The herd of 100 sheep is justified by comparison with the equipment for Cato's oliveyard (*de Agr*. 10), which included a herd of this number. Foraging is assumed to have taken place either on site using fallowed land or externally to the sites in areas not covered by the site territories, of which there is over 230,000ha.

Table 8.15. Calculating additional calories from animal products

			Farm		Villa	
Animal	Product	Annual calories per animal	Number of animals	Calories	Number of animals	Calories
Pig	meat	389,799	2	779,599	2	779,599
Sheep	milk	57,510	6	345,060	100	5,751,000
Goat	milk	126,891	2	253,782	2	253,782
Total annual calories				1,378,441		6,784,381
Daily calories				3,777		18,587

These results show that even a small peasant farm could produce enough through small-scale animal rearing to support at least one more person per farm, which could have important consequences for years of bad crop production. Looking at figures for the whole study area, the 535 farms could have produced enough animal products to support 532-1036 additional people in the area, whilst villas could support higher numbers between 3196-6221. Using the quarter-fallowed highest yielding intercropping model, (17-34 people/km^2), this figure is raised to 21-41 people/km^2 with the addition of animals.

An additional model would be to look at actual faunal assemblages for sites and create a model for animal rearing on this basis. Although a problematic exercise due to, amongst other problems, taphonomic processes, and unequal recovery and number of diagnostic bones for different species (Davis 1987: 35-36), it is nonetheless an interesting exercise to investigate such assemblages. The best example in the area is that of Monte Gelato, where the Early Imperial contexts showed a dominance of pig breeding. Although we cannot be sure over what length of time these bones were deposited, it is nonetheless interesting to attempt some sort of model. The assemblage identified 296 individual specimens, of which 6.8% were cattle, 21.6% were caprine and 71.6% were pig (King 1997: 385, tab. 66). Obviously this assemblage is not reflective of a year's diet as bones were deposited over a longer period, however, it is also likely that they are not reflective of the entire consumption of bones throughout that same time period due to factors such as taphonomic destruction. The assemblage was therefore modelled in its entirety to gauge the effect of the full composition of animals (Table 8.16). Cattle were assumed to be producing milk rather meat, and pigs were slaughtered at two years. Caprines were divided into a herd with a sheep:goat ratio of 10:1

Table 8.16 The Monte Gelato model for animal-rearing

Animal	Product	Annual calories per animal	Number of animals	Calories
Pig	meat	389,799	212	82,637,452
Sheep	milk	57,510	58	3,335,580
Goats	milk	923,431	6	2,537,820
Cattle	milk	923,431	20	5,540,589
		Total annual calories		94,051,440
		Daily calories		257,675
		People supported		67-132

This model supports between 67-132 people on the site. If we scale this down (as this represents a long deposition period), we may assume that the cattle number could actually represent two working animals, and so the remaining animal numbers may be scaled down in the same manner. The results in Table 8.17 show that, even when scaled down, production of animal products alone could still support between 7-13 people per year, on top of any other crop cultivation on the site. This last hypothetical model is for comparison with the Delano Smith model, which could support 5-10 people per year on a villa site. These figures compare well, but with a very different composition of animals.

Table 8.17 Scaled down Monte Gelato model for animal-rearing

Animal	Product	Annual calories per animal	Number of animals	Calories
Pig	meat	389,799	21	8,185,785
Sheep	milk	57,510	6	345,060
Goats	milk	923,431	1	923,431
		Total annual calories		9,454,277
		Daily calories		25,902
		People supported		7-13

The Monte Gelato model will not be used in further analysis due to inherent problems with the recovery and modelling of such skeletal assemblages. However, they have provided interesting comparisons, and further work may be done with such data.

8.4 Production figures for sample sites

As one possible reason for low production figures was the number of sites, it was decided to test the effect of additional sites within the study area. A random sample of sites was generated within the study area and added to the existing known sites. Their production was calculated in the same way as previous models. It has been stated previously that survey data rarely provides a full picture of settlement in a landscape, and that such results are merely "*palimpsests*" (Cambi 1999: 115; see Chapter 2). By randomly generating sites, we may therefore re-populate the landscape and test the effect of higher levels of production.

In Chapter 2.2.4 recovery rates of field survey were briefly discussed, and it was noted that, for the Albegna Valley survey near our study area, a 20-33% recovery rate was estimated (Cambi 1999: 121). This would mean that for our study area the number of rural sites would number approximately 1,605 farms and 1,962 villas using the 33% recovery rate.

Within *Idrisi* it was not possible to generate random sites that did not result in overlapping territories. However, in *ArcGIS* it was possible to generate points that could avoid certain areas (i.e. those areas already occupied by the known farms and villas) and could be spaced over specific distances (i.e. the potential territory of the sample sites). This ensured that any overlap was only due to the pre-existing known sites. These sites were then added to the pre-existing site maps. Both the known and sampled sites were then analysed together in the same way as before, with the construction of 12 and 100 *iugera* buffers and calculation of production according to different models. Some sites fell just outside the study are when modelled and so totals instead came to 1,529 farms and 1,866 villas (a 35% and 29% recovery rate respectively). This was considered sufficient for modelling purposes.

Table 8.18 shows that a system of wheat monoculture in the study area can hypothetically support very high population densities, up to a maximum of 157 people/km^2. On comparison with the postulated population densities of other scholars we can see that the area is now potentially capable of far exceeding these figures in certain circumstances (Figures 8.9-10), though the low yield of 4:1 can only achieve this with a heavy sowing rate. Again the quarter-fallow models were considered most representative and used to compare all sample models (Figure 8.11, page 370).

Table 8.18. Supported population density based on sample sites compared with previous model (continued overleaf)

modii/iugerum	Yield	Model	Fallowing	Sample sites Population		Known sites Population density	
				min	max	min	max
10	15:1	Arable only	Continual cropping	81	157	31	60
			¼ fallow	61	118	23	45
			½ fallow	42	82	16	31
			¾ fallow	20	39	8	15
5	15:1	Arable only	Continual cropping	40	79	15	30
			¼ fallow	30	59	11	22
			½ fallow	21	41	8	15
			¾ fallow	10	20	4	7
10	8:1	Arable only	Continual cropping	37	71	14	27
			¼ fallow	27	54	11	21
			½ fallow	20	39	8	15
			¾ fallow	9	18	4	7
5	8:1	Arable only	Continual cropping	18	36	7	14
			¼ fallow	14	27	5	10
			½ fallow	10	20	4	7
			¾ fallow	5	9	2	3
10	4:1	Arable only	Continual cropping	18	36	7	14
			¼ fallow	14	27	5	10
			½ fallow	10	20	4	7
			¾ fallow	5	9	2	3

Table 8.18 Cont.

modii/iugerum	Yield	Model	Fallowing	Sample sites Population min	Sample sites Population max	Known sites Population density min	Known sites Population density max
5	4:1	Arable only	Continual cropping	6	11	2	5
			¼ fallow	4	8	2	3
			½ fallow	4	7	1	3
			¾ fallow	1	3	1	1
10	15:1	Intercropping	Continual cropping	56	110	21	41
			¼ fallow	46	90	17	34
			½ fallow	37	72	14	27
			¾ fallow	26	51	10	19
5	15:1	Intercropping	Continual cropping	36	71	13	26
			¼ fallow	31	61	12	23
			½ fallow	27	52	10	19
			¾ fallow	21	41	8	15
10	8:1	Intercropping	Continual cropping	34	67	13	25
			¼ fallow	30	58	11	22
			½ fallow	26	51	10	19
			¾ fallow	21	40	8	15
5	8:1	Intercropping	Continual cropping	25	49	9	18
			¼ fallow	23	45	8	16
			½ fallow	21	41	8	15
			¾ fallow	18	36	7	13
10	4:1	Intercropping	Continual cropping	22	42	8	16
			¼ fallow	20	40	8	15
			½ fallow	20	39	7	14
			¾ fallow	17	34	6	12
5	4:1	Intercropping	Continual cropping	19	37	7	14
			¼ fallow	18	35	7	13
			½ fallow	18	35	7	13
			¾ fallow	17	33	6	12

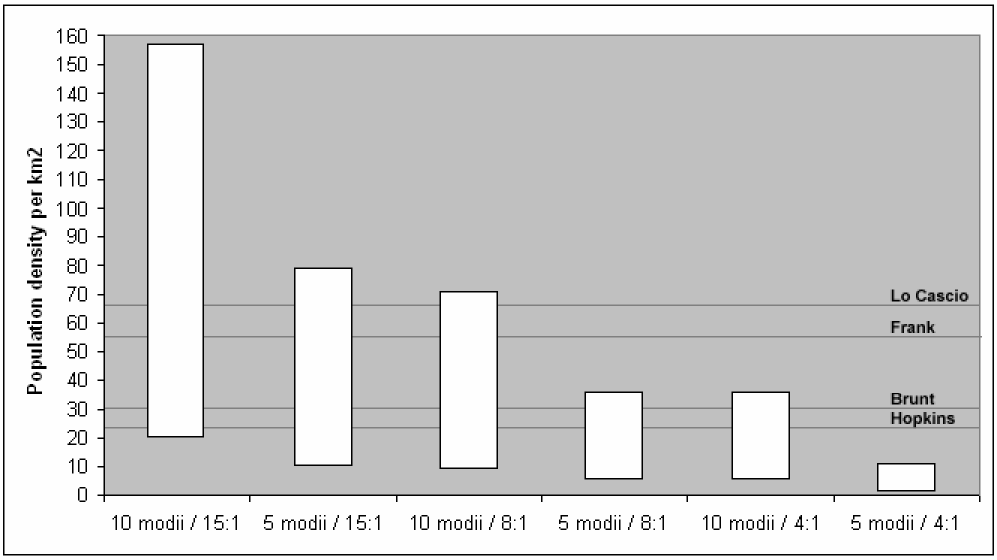


Figure 8.9 Comparison of sample arable monoculture yield models with previous demographic estimates (based on total populations including slaves)

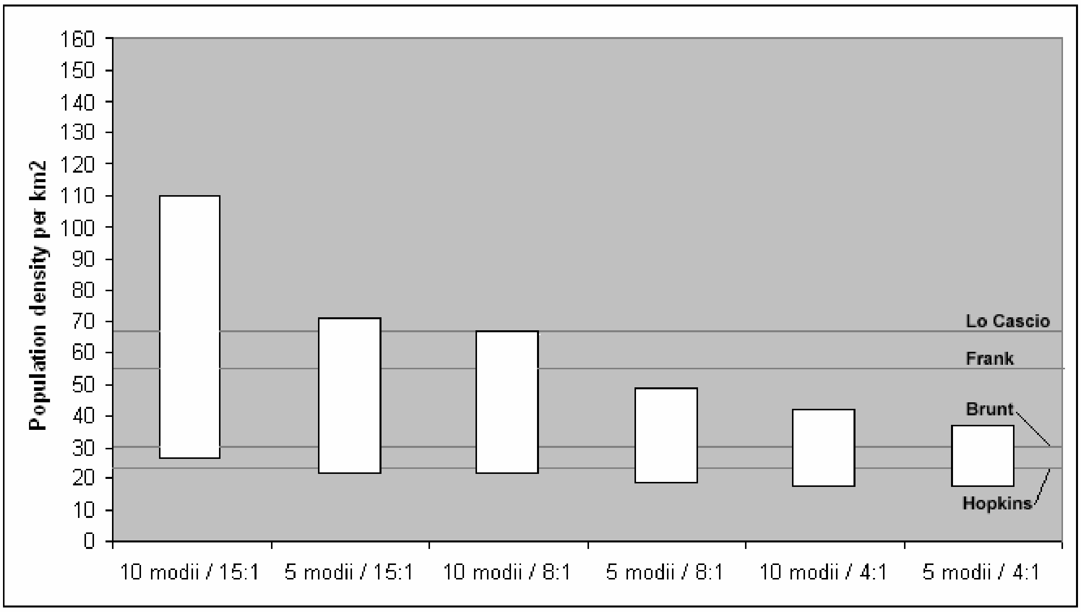


Figure 8.10 Comparison of sample intercropping yield models with previous demographic estimates (based on total populations including slaves)

Possibly the most important factor shown by these sample results was that the 4:1 yield for cereals, whilst completely insufficient when cultivated alone, could actually support a farm household of between 8-18 people when fallowed and sown in conjunction with an olive crop. This is a much higher average figure than was produced for the known sites (3-6 people per farm). It must be noted that as the sample was random, no account was taken for the quality of land. From the results in Chapter 5 it was seen that the majority of sites fell on land that was very suitable for arable agriculture. The random sample, conversely, fell on a variety of different land qualities, thereby creating an overall production figure that was possibly lower than may be expected if the cultivators choose better quality land. Were the landscape to be repopulated with known sites rather than random ones, via resurvey, we may therefore assume that higher numbers could be supported through increased production potential. Despite these caveats, all of the results produce high population densities with even the 4:1 yield supporting 17-37 people/km^2 when cultivated with olives and using sample sites.

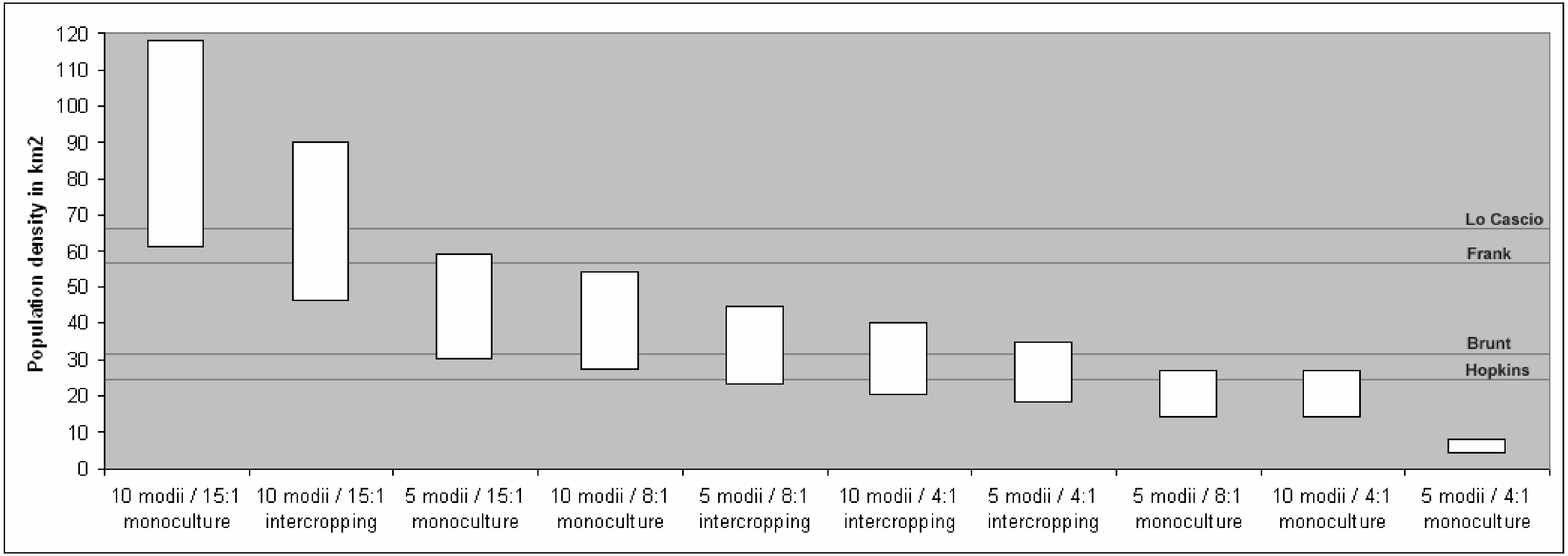


Figure 8.11 Comparison of monoculture and intercropping models for all sample yields with one-quarter fallowing regime

8.5 Surplus and urban dependency

It has been suggested by various scholars that most towns (not including Rome) 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 (Horden 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. Using the models created in this chapter the next stage is to assess the potential surplus, and how many non-productive people this could have supported.

8.5.1 Town populations

Surplus was an important factor within agricultural production, not just for rural populations to guard against poor harvests, but also to support the non-productive populations such as the army or town and city-dwellers. Garnsey (1999: 25) has argued that around 10% of the population of the Mediterranean were likely to have been urban residents with little or no access to cultivable land. This urban population, with no real means of producing their own food, would have relied either on industry and trade, the corn dole, or the euergetism of the rich to provide a food supply. Therefore poorer town-dwellers were theoretically more at risk than rural populations when it came to poor harvests. Indeed we hear not only of the poor, but the elite also, plundering the countryside for grass and shrubs to eat in times of extreme shortage (Galen 6.686, 749; in Nutton 1995: 360). However, when elite urban residents were landlords such problems would be abated to some extent, as they would have a claim over the produce of their land.

We cannot know the population of the urban centres of antiquity, as there is little evidence other than the physical remains or extents of the towns. Explicit population figures in the sources are rare, and relate to cities outside of Italy. Additionally, these figures are highly likely to incorporate the population of their surrounding territory as well as the centre itself (Duncan-Jones 1982: 260, n.4): towns and their hinterlands were considered united as a single legal and economic unit. Some urban occupants may have had some access to land, but the majority of non-productive urban residents tended to live off their rural counterparts. This would have been obtained in the form of rents, sale or trade of goods, or other services available in the towns (Garnsey 1999: 29).

Hopkins (1978: 68-69, tab. 1.2) argued that Rome itself had a free population of 600,000 whilst the 434 towns of Roman Italy had a total population in the region of 500,000 people, and the total number of urban slaves was 800,000. Divided equally would equate to an average free population of 1,152 per town, though this has been argued to be very low (Lo Cascio 1999). Adding Hopkins' urban slaves to this would still only raise the figure to 1,990 per town. This is a problematic approach. The population size of towns and other urban centres may instead be determined to some extent from their physical archaeological remains, for example the extent of town walls. However, this type of information is not readily available for the majority of towns in the study area. Only Falerii Novi has a full town plan, as this is the only centre to have been subject to an intensive geophysical survey of the entire walled area of 30.6ha (Keay *et al.* 2000). Of course, the citizens of a town did not always live within the walled region, if indeed a town had a wall at all (as is often the case in the Sabine region), and not all the area within a walled centre need have been occupied.

The populations of large towns, such as Ostia or Pompeii have been variously guessed at, based on the archaeological remains. These range from around 20-60,000 for Ostia (Meiggs 1960: 532-534; Packer 1967: 86; in Duncan-Jones 1982: 276, n.7) and 15,000 for Pompeii (Beloch 1898: 274; in Duncan-Jones 1982: 276, n.7). These are very high population figures compared to the previous estimates, however, and few of the urban centres of South Etruria or Sabina were likely to have been as large as these towns. Estimates for populations of other towns across the peninsula have been carried out and compared to modern figures (Table 8.19; Duncan-Jones 1982: 273). The table shows that the estimated range of urban populations was wide, from *c*.1,000 up to 23,000. It also demonstrates that, in many cases, towns have shrunk as well as grown since the Roman period. However, it is interesting to note that the figures for the smaller towns are comparable to figures put forward below for the urban centres in the Tiber Valley.

Table 8.19. The estimated population of Roman urban centres (after Duncan-Jones 1982: 273, tab. 7)

Town	Estimated total population	Population of modern centre (1951)
Spoletium	23,000	13,729
Comum	18,900 / 22,500	56,937
Pisaurum	12,600 / 23,800	34,647
Sentinum	3,500 / 7,200	3,598
Corfinium	2,480 / 2,820	2,047
Petelia	2,480	819
Rudiae	1,980 / 2,430	-
Fabrateria	1,360 / 1,650	295
Saturnia	1,210 / 2,220	526

To create a benchmark for the urban population in the study area, the notional figures put forward by Witcher (2005; see Section 8.1) will be used. These, once applied to the study area only (rather than the whole *suburbium*), equated to an urban population of between 15,700-61,500 (Table 8.20).

Table 8.20 Potential population of towns in the Tiber Valley (after Witcher 2005, tab. 2)

	Town class	Min population	Max population
Otricoli	Town	3,000	10,000
Forum Novum	Small town	500	3,000
Falerii Novi	Town	3,000	10,000
Sutri	Small town	500	3,000
Nepi	Small town	500	3,000
Nazzano	Road Station*	200	500
Capena	Small town	500	3,000
Cures Sabini	Small town	500	3,000
Forum Clodii	Small town	500	3,000
Lucus Feroniae	Town	3,000	10,000
Veii	Town	3,000	10,000
Nomentum	Small town	500	3,000
TOTAL		15,700	61,500

*Not actually a road station in designation. Contains monumental structures but size is unknown, likely to have been small in this period but larger than a village (Witcher pers. comm.)

8.5.2 Modelling Surplus

In the Roman period it has 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. In order to gauge provisioning of the urban centres, some quantification of likely surplus was therefore attempted. This was done by assuming a standard household for farms and villas, and calculating total rural population using both the known sites and the sample sites.

As in Section 8.1, a household of six people per farm and twenty-five people per villa was assumed. This would mean a total rural population of 19,535 in the Early Imperial period (3,210 for farms and 16,325 for villas), or 55,824 for the sample sites. This figure was therefore subtracted from the original number supported to give a number of adults supported by the surplus only. In doing this we may hypothesise how much surplus may have been available to unproductive urban populations. Though we do not count children or the elderly in this model, the research into nutritional requirements showed that the young required more food than adults, whilst the elderly required much less. This was therefore assumed to have balanced out requirements and the figure for male and female adults was used to stand for the whole household.

It is clear from Table 8.21 that, with the exception of the lower yields and extensive fallow, the study area was capable of producing a large surplus and therefore supporting a high number of urban dwellers. The 15:1 yield of Varro was capable of producing sufficient surplus for up to 10,387 people per town in the study area, 124,649 in total (over twice Witcher's maximum urban estimate). The sample sites show that a much larger population was supported with the higher yielding models, but with the low yields or extensive fallow the shortfalls were more serious. Therefore, these models demonstrate the potential for the rural population to support a very large, non-productive urban population. However, in bad years this could cause disastrous problems if the population was as large as has been postulated here and would mean that they would need some other way of feeding themselves, for example through more long-distance exchange mechanisms.

Table 8.21 Average urban population per town supported by basic surplus of monoculture

		Total range Known sites min	Total range Known sites max	Total range Sample sites min	Total range Sample sites max	Per town Known sites min	Per town Known sites max	Per town Sample sites min	Per town Sample sites max
15:1 10 modii	Continual cropping	54,531	124,649	175,978	361,070	4,544	10,387	14,665	30,089
	¼ fallow	36,014	88,603	127,100	265,919	3,001	7,384	10,592	22,160
	½ fallow	18,956	55,395	82,388	178,878	1,580	4,616	6,866	14,907
	¾ fallow	-1,019	16,511	29,343	75,616	-85	1,376	2,445	6,301
15:1 5 modii	Continual cropping	17,500	52,560	78,225	170,774	1,458	4,380	6,519	14,231
	¼ fallow	8,241	34,537	53,785	123,196	687	2,878	4,482	10,266
	½ fallow	-289	17,932	31,428	79,675	-24	1,494	2,619	6,640
	¾ fallow	-10,276	-1,511	4,905	28,042	-856	-126	409	2,337
8:1 10 modii	Continual cropping	14,525	46,769	69,187	153,180	1,210	3,897	5,766	12,765
	¼ fallow	6,010	30,193	47,007	110,001	501	2,516	3,917	9,167
	½ fallow	-1,047	16,455	28,993	74,933	-87	1,371	2,416	6,244
	¾ fallow	-11,020	-2,959	2,646	23,644	-918	-247	220	1,970
8:1 5 modii	Continual cropping	-2,505	13,617	24,826	66,822	-209	1,135	2,069	5,569
	¼ fallow	-6,763	5,329	13,736	45,233	-564	444	1,145	3,769
	½ fallow	-10,291	-1,540	4,729	27,699	-858	-128	394	2,308
	¾ fallow	-15,278	-11,247	-8,445	2,054	-1,273	-937	-704	171
4:1 10 modii	Continual cropping	-2,505	13,617	24,826	66,822	-209	1,135	2,069	5,569
	¼ fallow	-6,763	5,329	13,736	45,233	-564	444	1,145	3,769
	½ fallow	-10,291	-1,540	4,729	27,699	-858	-128	394	2,308
	¾ fallow	-15,278	-11,247	-8,445	2,054	-1,273	-937	-704	171
4:1 5 modii	Continual cropping	-13,936	-8,635	-5,690	7,418	-1,161	-720	-474	618
	¼ fallow	-15,336	-11,360	-9,151	679	-1,278	-947	-763	57
	½ fallow	-16,006	-12,666	-10,529	-2,003	-1,334	-1,055	-877	-167
	¾ fallow	-18,135	-16,810	-16,074	-12,797	-1,511	-1,401	-1,339	-1,066

It has been argued that Roman agriculture was incapable of producing a consistent surplus and often suffered from serious crop failures. This was due to the level of technology, and the subsistence strategies of the majority of the peasantry (Evans 1981: 441; Garnsey 1999: 25). To counteract the effects of bad harvests, a percentage of the crop was often stored for these times (Section 6.2.3). Modern Greek peasants from Methana are cited as storing two years' supply of wheat and four of olive oil as a 'normal surplus' (Forbes 1982; in Forbes 1989). This would mean that a surplus of the scale indicated above would have to be reduced significantly to account for such actions. Even if we assume the reservation for only an additional one year's worth of food, we see that the supported population is dramatically reduced (Table 8.22).

Table 8.22 Urban population supported by surplus when one year's supply is stored by the rural population

		Total range Known sites		Total range Sample sites		Per town Known sites		Per town Sample sites	
		min	max	min	max	min	max	min	max
15:1 10 modii	Continual cropping	34,996	105,114	156,443	341,535	2,916	8,759	13,037	28,461
	¼ fallow	16,479	69,068	107,565	246,384	1,373	5,756	8,964	20,532
	½ fallow	-579	35,860	62,853	159,343	-48	2,988	5,238	13,279
	¾ fallow	-20,554	-3,024	9,808	56,081	-1,713	-252	817	4,673
15:1 5 modii	Continual cropping	-2,035	33,025	58,690	151,239	-170	2,752	4,891	12,603
	¼ fallow	-11,294	15,002	34,250	103,661	-941	1,250	2,854	8,638
	½ fallow	-19,824	-1,603	11,893	60,140	-1,652	-134	991	5,012
	¾ fallow	-29,811	-21,046	-14,630	8,507	-2,484	-1,754	-1,219	709
8:1 10 modii	Continual cropping	-5,010	27,234	49,652	133,645	-418	2,270	4,138	11,137
	¼ fallow	-13,525	10,658	27,472	90,466	-1,127	888	2,289	7,539
	½ fallow	-20,582	-3,080	9,458	55,398	-1,715	-257	788	4,617
	¾ fallow	-30,555	-22,494	-16,889	4,109	-2,546	-1,874	-1,407	342
8:1 5 modii	Continual cropping	-22,040	-5,918	5,291	47,287	-1,837	-493	441	3,941
	¼ fallow	-26,298	-14,206	-5,799	25,698	-2,191	-1,184	-483	2,142
	½ fallow	-29,826	-21,075	-14,806	8,164	-2,486	-1,756	-1,234	680
	¾ fallow	-34,813	-30,782	-27,980	-17,481	-2,901	-2,565	-2,332	-1,457
4:1 10 modii	Continual cropping	-22,040	-5,918	5,291	47,287	-1,837	-493	441	3,941
	¼ fallow	-26,298	-14,206	-5,799	25,698	-2,191	-1,184	-483	2,142
	½ fallow	-29,826	-21,075	-14,806	8,164	-2,486	-1,756	-1,234	680
	¾ fallow	-34,813	-30,782	-27,980	-17,481	-2,901	-2,565	-2,332	-1,457
4:1 5 modii	Continual cropping	-33,471	-28,170	-25,225	-12,117	-2,789	-2,348	-2,102	-1,010
	¼ fallow	-34,871	-30,895	-28,686	-18,856	-2,906	-2,575	-2,391	-1,571
	½ fallow	-35,541	-32,201	-30,064	-21,538	-2,962	-2,683	-2,505	-1,795
	¾ fallow	-37,670	-36,345	-35,609	-32,332	-3,139	-3,029	-2,967	-2,694

Assuming no fallow, the highest figure would be for the 10 *modii* sowing rate and 15:1 yield, supporting a maximum of 124,649 people (Table 8.21), and 105,114 (Table 8.22) if allowing storage for an extra year. This is still a high figure, but such yields could not necessarily be sustained, even if they were achieved in the first instance. Lower yields and lower sowing rates would lead to a negligible surplus, if any at all, and in the case of the 4:1 yield could not support the rural population, let alone an urban one. Sample sites improved this situation somewhat, but not when storage was taken into consideration. Therefore, should the area be subject to any low yields or crop failures, the effect on any non-productive population could have been disastrous. We cannot know how often local towns were left short of food, but this is where comparisons with Rome are useful. Garnsey documents 37 incidents of food shortage in Rome which led to social disturbances between 189-36 BC (Garnsey 1988: 193-217) – an average of one every four years, which implies that interruptions in the food supply may have occurred fairly frequently in the study area.

Many models have been presented here and so, to simplify, the intercropping model is presented in summary, as this is believed to be most representative of Roman farming practice. As stated above, the intercropping model assumes an initially high yield with a heavy sowing rate, but the yield is halved. Table 8.23, however, demonstrates that this type of production would have produced sufficient to supply the urban centres in the study area, even with allowance for fallowing, though incorporating storage limits the supply to the urban centres and can only provide sufficient to match Witcher's estimate (15,700-61,500) in the higher yielding categories.

Table 8.23 Urban population supported according to the intercropping models

		Total urban population				Total urban population minus storage			
		Known sites:		Sample sites:		Known sites:		Sample sites:	
		min	max	min	max	min	max	min	max
15:1 10 modii	Continual cropping	31,610	80,029	117,086	246,424	12,075	60,494	97,551	226,889
	¼ fallow	22,351	62,005	92,645	198,846	2,816	42,470	73,110	179,311
	½ fallow	13,822	45,400	70,288	155,323	-5,713	25,865	50,753	135,788
	¾ fallow	3,834	25,957	43,764	103,689	-15,701	6,422	24,229	84,154
15:1 5 modii	Continual cropping	13,090	43,975	68,198	151,255	-6,445	24,440	48,663	131,720
	¼ fallow	8,461	34,965	55,980	127,469	-11,074	15,430	36,445	107,934
	½ fallow	4,197	26,664	44,803	105,711	-15,338	7,129	25,268	86,176
	¾ fallow	-796	16,943	31,542	79,897	-20,331	-2,592	12,007	60,362
8:1 10 modii	Continual cropping	11,605	41,085	63,685	142,468	-7,930	21,550	44,150	122,933
	¼ fallow	7,347	32,797	52,594	120,879	-12,188	13,262	33,059	101,344
	½ fallow	3,819	25,928	43,587	103,345	-15,716	6,393	24,052	83,810
	¾ fallow	-1,168	16,221	30,414	77,700	-20,703	-3,314	10,879	58,165
8:1 5 modii	Continual cropping	3,091	24,511	41,506	99,294	-16,444	4,976	21,971	79,759
	¼ fallow	962	20,366	35,961	88,498	-18,573	831	16,426	68,963
	½ fallow	-803	16,931	31,457	79,730	-20,338	-2,604	11,922	60,195
	¾ fallow	-3,296	12,077	24,869	66,907	-22,831	-7,458	5,334	47,372
4:1 10 modii	Continual cropping	175	18,834	33,173	83,072	-19,360	-701	13,638	63,537
	¼ fallow	-1,225	16,109	29,711	76,332	-20,760	-3,426	10,176	56,797
	½ fallow	-1,896	14,802	28,332	73,647	-21,431	-4,733	8,797	54,112
	¾ fallow	-4,025	10,658	22,786	62,851	-23,560	-8,877	3,251	43,316
4:1 5 modii	Continual cropping	-2,628	13,378	26,239	69,573	-22,163	-6,157	6,704	50,038
	¼ fallow	-3,327	12,016	24,510	66,207	-22,862	-7,519	4,975	46,672
	½ fallow	-3,662	11,365	23,823	64,870	-23,197	-8,170	4,288	45,335
	¾ fallow	-4,726	9,294	21,053	59,476	-24,261	-10,241	1,518	39,941

Incorporating animal rearing onto farms and villas would not have made an enormous difference to population density supported. Overall, animal husbandry following the two models put forward by Delano Smith (Section 8.3.3) would have only added 3,728-7,257 people to the overall supported population. Density only increased by approximately three people/km^2. The difference animal rearing made on a site-by-site basis, however, is far more important than its contribution to the overall density. As we saw in Section 8.3.3, it added sufficient calories to support 1-2 extra people per farm and 5-10 people per villa, which could have important consequences in years of low yields.

8.5.3 The urban-rural split

Returning to the division of population between the countryside and towns, a further model may be carried out. If we assume the rural population to have been six per farm and twenty-five per villa, the percentage of total population supported living in towns may be analysed. Taking the average figure between minimum and maximum supported population for each model (a 'typical' nutritional intake), the percentage split was calculated (Table 8.24). Those figures that fall within the postulated range of up to 35% urban residency are highlighted in grey.

It can be seen in the table that the division of population would have been unusual for many of the models, with a heavy urban bias for the high yielding models. However, we might argue that much of this surplus would have gone to Rome, had the local urban need been fulfilled. This model also highlights those models that are inadequate for provisioning urban populations. The models that do not produce enough food are shown as 0. For example, we might argue that, were Columella's yield of 4:1 common in the study area, then only the intercropping farming system could have supplied urban centres as well as a rural population, unless there were a higher number of rural settlements.

Table 8.24 Percentage of total population resident in the towns

Model	Fallowing	Mono storage	Inter storage	Mono	Mono sample storage	Mono sample	Inter	Inter sample	Inter sample storage
15:1 10 modii	Continual cropping	78	65	82	93	93	74	90	89
	1/4 fallow	69	54	76	90	91	68	88	87
	1/2 fallow	47	34	66	85	87	60	85	83
	3/4 fallow	0	0	28	63	73	43	79	74
15:1 5 modii	Continual cropping	44	32	64	84	86	59	85	82
	1/4 fallow	9	10	52	78	82	53	82	79
	1/2 fallow	0	0	31	65	74	44	79	74
	3/4 fallow	0	0	0	0	46	29	74	65
8:1 10 modii	Continual cropping	36	26	61	82	85	57	84	81
	1/4 fallow	0	3	48	75	80	51	82	77
	1/2 fallow	0	0	28	62	73	43	79	73
	3/4 fallow	0	0	0	0	40	28	73	64
8:1 5 modii	Continual cropping	0	0	22	57	70	41	78	72
	1/4 fallow	0	0	0	34	60	35	76	69
	1/2 fallow	0	0	0	0	45	29	74	65
	3/4 fallow	0	0	0	0	0	18	70	57
4:1 10 modii	Continual cropping	0	0	22	57	70	33	75	66
	1/4 fallow	0	0	0	34	60	28	73	63
	1/2 fallow	0	0	0	0	45	25	72	62
	3/4 fallow	0	0	0	0	0	15	69	54
4:1 5 modii	Continual cropping	0	0	0	0	4	22	71	59
	1/4 fallow	0	0	0	0	0	18	70	57
	1/2 fallow	0	0	0	0	0	16	69	56
	3/4 fallow	0	0	0	0	0	10	67	51

The table highlights that the only 'safe' strategy to supply local towns in nearly all circumstances was intercropping. Had the area relied solely on monoculture of grain, it was liable to extreme food shortages in times of low yield.

Although any models disguise the complexity of production what these models show is the likelihood of any particular strategy being followed in the study area. The results for town supply were divided into three groups:

- Those that could not feed towns (red)
- Those that could feed towns with a rural split of up to 35% (yellow)
- Those that produced enough for Rome as well as local towns (green)

These were then organised in a table to determine which factors played the most important role in production (Table 8.25)

Table 8.25 Analysis of models in Groups I-III (based on Table 8.24)

		Mono storage	Inter storage	Mono	Mono sample storage	Mono sample	Inter	Inter sample	Inter sample storage
15:1 10 modii	Continual cropping	Green	Green	Green	Green	Green	Green	Green	Green
	1/4 fallow	Green	Green	Green	Green	Green	Green	Green	Green
	1/2 fallow	Green	Yellow	Green	Green	Green	Green	Green	Green
	3/4 fallow	Red	Red	Yellow	Green	Green	Green	Green	Green
15:1 5 modii	Continual cropping	Green	Yellow	Green	Green	Green	Green	Green	Green
	1/4 fallow	Yellow	Yellow	Green	Green	Green	Green	Green	Green
	1/2 fallow	Red	Red	Yellow	Green	Green	Green	Green	Green
	3/4 fallow	Red	Red	Red	Red	Green	Yellow	Green	Green
8:1 10 modii	Continual cropping	Yellow	Yellow	Green	Green	Green	Green	Green	Green
	1/4 fallow	Red	Yellow	Green	Green	Green	Green	Green	Green
	1/2 fallow	Red	Red	Yellow	Green	Green	Green	Green	Green
	3/4 fallow	Red	Red	Red	Red	Green	Yellow	Green	Green
8:1 5 modii	Continual cropping	Red	Red	Yellow	Green	Green	Green	Green	Green
	1/4 fallow	Red	Red	Red	Yellow	Green	Yellow	Green	Green
	1/2 fallow	Red	Red	Red	Red	Green	Yellow	Green	Green
	3/4 fallow	Red	Red	Red	Red	Red	Yellow	Green	Green
4:1 10 modii	Continual cropping	Red	Red	Yellow	Green	Green	Yellow	Green	Green
	1/4 fallow	Red	Red	Red	Yellow	Green	Yellow	Green	Green
	1/2 fallow	Red	Red	Red	Red	Green	Yellow	Green	Green
	3/4 fallow	Red	Red	Red	Red	Red	Yellow	Green	Green
4:1 5 modii	Continual cropping	Red	Red	Red	Red	Yellow	Yellow	Green	Green
	1/4 fallow	Red	Red	Red	Red	Red	Yellow	Green	Green
	1/2 fallow	Red	Red	Red	Red	Red	Yellow	Green	Green
	3/4 fallow	Red	Red	Red	Red	Red	Yellow	Green	Green

The primary restriction in nearly all models was the extensive fallow with storage also playing an important role in limiting supply. Low yields were the next most influential factor, whilst monoculture was less reliable than intercropping in a stable urban supply.

8.6 Conclusions

All of these models have shown similar trends. In all models increasing the sowing rate could offset the problem of low yields. However, whether this was a feasible strategy at the time cannot be known, as it was highly dependent on previous yields or the ability to purchase more seed through some form of exchange.

Monoculture was shown to have been slightly more productive than intercropping with the higher cereal yields, but less productive than intercropping with the lower yields. This shows that those in less fertile areas for wheat would have been better off producing a combination of crops. This is also evident in the surplus models. With a 4:1 yield and 5 *modii* sowing rate, monoculture would have been insufficient to supply even the rural population, let alone supporting any non-productive members of the community. With intercropping, however, the surplus vastly increased in the lower yield brackets and could support an urban population of up to 1,000 people per town. The addition of sample sites, however, could support town populations at even the lowest yields with storage.

If we were therefore to take Varro's figure of 15:1 as the average yield of Etruria, then the supported urban population could have been very high indeed. With the known sites producing supported figures of up to 10,387 people as a maximum per town for monoculture and 6,669 for intercropping, then this model would go some way towards showing Etruria's capability of supporting not only its local urban population, but contributing towards that of Rome also. If one assumes local towns to have had a maximum population of 2,000 then the maximum production model for known sites would produce enough food to support between 56,028 (intercropping) and 100,668 (monoculture) inhabitants of the capital. For sample sites this maximum supply would feed between 222,420 (intercropping) and 336,468 (monoculture) – one-quarter to one third of the postulated population of one million for Rome (Rickman 1980). These last figures are, of course, the absolute maximum production capability of the area, assuming Varro's statements to have been representative. Given the variability of yields and likelihood of fallowing, the actual surplus figures were likely to have been much lower and as we have seen, in the low yielding cases, not sufficient to feed local towns let alone Rome.

9 CONCLUSION

This thesis has presented a number of different models for agricultural production within the study area. These models have used many variables which each present a range of possibilities for the carrying capacity of the area. Obviously what is offered here is a method rather than an answer – these figures cannot be taken to be exact representations of production for the Roman period. Instead, it is suggested that, were the figures quoted by certain sources true, or certain production strategies followed, then the resulting effect on the population would be as it is presented here. Though many models have been produced, however, only a few are considered to be ‘likely scenarios’ in the context of Early Imperial agriculture. This narrower range equates well with the higher estimates for the Roman population, though it is not a straightforward matter to apply these ranges wholesale across the peninsula, as will be discussed towards the end of this chapter.

Although a number of different types of analysis have taken place within this study, the overall aim was to establish likely production figures and their demographic implications. In order to look at production, however, assessments of site size and locational analysis first needed to be carried out to investigate where certain settlement types (in this case farms and villas) were located and whether they related to specific resources. By collating all contemporary records of site size in the Roman period (Chapter 3), it was possible to compare the evidence. It showed that, as could be expected, the literary evidence tended towards references to unusually-sized plots (either very small or very large). Conversely the evidence from the *agrimensores* and the cadastral evidence showed much more diversity in site size and represented the medium-sized plots that were absent from the literary sources. Through locational analysis in Chapter 4 these sites were shown to have been preferentially located on certain types of resources. The vast majority of Roman rural sites seemed to conform to many of the stipulations outlined by the agronomists for optimal site location. In comparing the location of the Roman rural sites to that of the modern-day arable land it was also possible to see many similarities. There were, however, a few key differences, for example the underlying geology. The evidence suggests that Roman sites tended primarily to be situated on volcanic geology with none on alluvial sediments. Modern arable, however utilised alluvial geology heavily due to the richness of the soil, and the absence of Roman sites may either indicate a reluctance to use soils in flood plains, or the disappearance of sites underneath alluvial deposits.

Whilst Chapter 4 assessed site location in regards to how they were located in relation to the available resources, Chapter 5 looked at the rural sites from a different angle. Resources were assessed according to evidence from the Roman agronomists concerning the most desirable locations and resources for estates. This information was used to create suitability maps for different crops based on Roman perceptions of suitability, independent of the known sites and modern agriculture, and based entirely on the textual evidence. These maps highlighted those areas likely to have been most suitable for arable and olive cultivation in this period according to the agronomists. Overlaying the known Roman sites from field survey meant that a comparison could be made and the sites assessed to see if they followed similar criteria for farm location. This would not necessarily prove that Roman farmers were following this type of advice, because it may be that the agricultural treatises were based on common-sense knowledge of the subject and reflected contemporary practice. Results did show, however, that Roman sites were frequently located in sites thought desirable in the Roman period for different economic strategies – particularly wheat and oleoculture.

Chapter 6 outlined the different approaches of modern scholars to Roman agriculture. It also crucially discussed evidence for crop yields in the area from the Roman period to more recent times. This was not restricted to wheat, but also took into account evidence for oleoculture, viticulture, intercropping and animal rearing. Variety in production and risk avoidance strategies were also covered, including the most important factor of fallowing regimes known from the Roman period. The fact that Roman farmers practised a variety of fallowing regimes meant that any models of production would have to take this into account, as it would have a significant effect on crop yield.

In order to ascertain the number of people supported by these yields, nutritional requirements of agricultural labourers were assessed in Chapter 7. Firstly, demographic models put forward by a number of scholars were outlined in order to create comparative figures for the GIS model. The range of population densities put forward by modern scholars was from 13-64 people/km^2. The main factor noted with these models was that these tended to be national averages, and that the study area, being in close proximity to Rome, was likely to have been more densely populated than many other areas. Nutritional requirements were established based on workload, and for this there is useful evidence from both the agronomists' texts from the Roman period and ethnographic data. The main source used for establishing workload was the working year as outlined by Columella (*Rust*. 2.7.8-9). Using nutritional requirements based on data from the FAO as well as ancient evidence such as Cato's rationing of slaves (*de Agr*. 56) it was possible to model potential nutritional requirements of males and females, using stature derived from skeletal data and comparative evidence. Assuming an even gender split within the population meant that the average nutritional requirement was 1,059,840 calories annually, or 2,904 per day. Other gender ratios are of course possible, as well as differing workloads, and so a range of 1,951-3,798 kilocalories was used in further modelling.

Once nutritional requirement was estimated, it was then possible to begin modelling supported populations. To begin with, hypothetical territories based on the plot sizes established in Chapter 3 and a variety of crop yields were modelled. The composition of the diet had been investigated and the diet was likely to have composed mainly of cereals. Wheat production was likely to have predominated and was consequently used for basic modelling. The initial results were that the 4:1 yield, frequently cited as a national average, was not sufficient to support a household unless plot sizes were over 12 *iugera* in size. Also, the traditional *heredium* of 2 *iugera* could not support a household, even at the highest yields, without significant recourse to other food sources.

A great variety of production models were carried out in Chapter 8, and these are listed below in Table 9.1. Perhaps the most important consequence of the models was the same result as had been achieved through the hypothetical territory modelling – to exclude early on the possibility of low yields at less than 8:1 if carrying out cereal monoculture. The yields of 4:1 (and some even less) put forward by modern scholars as a national average have obscured local variation and probable production levels. Modelling demonstrated that plots reliant on cereal monoculture could not have supported high populations if below 12 *iugera* in size. This means that peasants operating on farms smaller than this would have had to follow much more intensive cultivation strategies, kept animals, foraged, hired themselves out as seasonal labourers, or a combination of these, in order to subsist.

Table 9.1. List of all models

Area	Crop	Yield	Sowing rate *mod/iug*	Maximum pop density supported
Entire area	Arable monoculture	15:1	10	679
Entire area	Arable monoculture	15:1	5	333
Entire area	Arable monoculture	8:1	10	305
Entire area	Arable monoculture	8:1	5	146
Entire area	Arable monoculture	4:1	10	92
Entire area	Arable monoculture	4:1	5	41
Entire area	Olive monoculture	879 kg/ha	-	638
2 *iugera*	Arable monoculture	15:1	5	0.23
5 iugera	Arable monoculture	15:1	5	2
12 iugera	Arable monoculture	15:1	5	7
40 iugera	Arable monoculture	15:1	5	19
100 iugera	Arable monoculture	15:1	5	42
12 & 100 *iugera*	Arable monoculture	15:1	10	58
12 & 100 *iugera*	Arable monoculture	15:1	5	29
12 & 100 *iugera*	Arable monoculture	8:1	10	27
12 & 100 *iugera*	Arable monoculture	8:1	5	13
12 & 100 *iugera*	Intercropping with olives	15:1 halved 512.5 kg/ha	10	56
12 & 100 *iugera*	Intercropping with olives	15:1 halved 512.5 kg/ha	5	41
12 & 100 *iugera*	Intercropping with olives	8:1 halved 512.5 kg/ha	10	40
12 & 100 *iugera*	Intercropping with olives	8:1 halved 512.5 kg/ha	5	33
12 & 100 *iugera*	Intercropping with olives	4:1 halved 512.5 kg/ha	10	31
12 & 100 *iugera*	Intercropping with olives	4:1 halved 512.5 kg/ha	5	30
12 & 100 *iugera*	Intercropping with olives and vines	15:1 halved 512.5 kg/ha	10	39 (66)
12 & 100 *iugera*	Intercropping with olives and vines	15:1 halved 512.5 kg/ha	5	22 (49)
12 & 100 *iugera*	Animal rearing	1,169 additional people supported annually		
12 & 100 *iugera* sample	Animal rearing	3,507 additional people supported annually		
12 & 100 *iugera* sample	Arable monoculture	15:1	10	145
12 & 100 *iugera* sample	Arable monoculture	15:1	5	71
12 & 100 *iugera* sample	Arable monoculture	8:1	10	65
12 & 100 *iugera* sample	Arable monoculture	8:1	5	31
12 & 100 *iugera* sample	Intercropping with olives	15:1 halved 512.5 kg/ha	10	142
12 & 100 *iugera* sample	Intercropping with olives	15:1 halved 512.5 kg/ha	5	102
12 & 100 *iugera* sample	Intercropping with olives	8:1 halved 512.5 kg/ha	10	102
12 & 100 *iugera* sample	Intercropping with olives	8:1 halved 512.5 kg/ha	5	82
12 & 100 *iugera* sample	Intercropping with olives	4:1 halved 512.5 kg/ha	10	79
12 & 100 *iugera* sample	Intercropping with olives	4:1 halved 512.5 kg/ha	5	70

The model considered to reflect most accurately the situation in the Early Imperial Tiber Valley was that of intercropping. Due to the inappropriate terrain for large-scale monoculture and the density of sites, it was considered the most likely strategy for agricultural production, and is still the situation within modern agriculture in many parts of the study area. The combination of crops meant that the most appropriate soil and topography would be used for each crop, meaning that yields should actually be higher per unit area. Although comparative studies based on production statistics showed this to be the case in reality, in some instances modelled yields were actually slightly lower than expected. This could have been for a number of reasons, most probably because of the typically biennial yield of the olive, meaning that an average production figure had to be used to compensate. Olive yields were noted as being notoriously difficult to establish and it is likely that the yield used may not accurately reflect actual production. However, the results obtained from known sites – a maximum of 41 people/km^2 – do compare well with the lower estimates of the demographers. If we assume that known sites only represent 33% of actual sites (Cambi 1999: 121), sample sites modelled at this rate would support a maximum of 79 people/km^2 – not far above the postulated demographic range (13-67 people/km^2). If in reality the recovery rate of sites were even lower, and many more archaeological sites remain undiscovered, then the population density would be even higher due to the consequent increase in exploited area.

As field survey cannot recover 100% of sites, sample sites were modelled in addition to the known sites. By modelling using the basis that the known sites reflected approximately one-third of the actual sites, results showed that a very high population density of up to 157 people/km^2 could be achieved in the study area. These models also produced plentiful surplus for urban provisioning.

In carrying out intercropping models for the lower yields the models showed that these systems were capable of producing much higher yields than their equivalent in monoculture. This meant that the yield of 4:1, previously excluded as insufficient to support a household, could consequently be reintroduced as a viable yield, even when halved to 2:1 for reduced intercropping yield.

Incorporating animal rearing onto farms and villas practicing intercropping would have added an additional 3,728-7,257 people to the total supported population. If these figures are added to the maximum model, this meant a maximum population density of 44 people/km^2 (compared with 41) for the known sites, and 113 per km^2 (compared with 79) for the sample sites, which equate to a middle-very high estimation of population density.

Questions of urban provisioning were approached in the models that incorporated likely surplus. The main aspect noted was that, although a high non-productive urban population could be supported with the higher yields, any shortfalls would have meant significant problems in supplying the towns. With the known sites, the 15:1 yield at a 5 *modii/iugerum* sowing rate could support a total urban population of 8,241-34,536 people with a fallow of one-quarter. However the next yield category down, of 8:1 at the same sowing rate could only support between –6,762 (i.e. a shortfall for the rural population) and 5,329 people in total.

The urban-rural split was investigated next, and showed how high yielding models could have contributed to a high urban population within the studied region, and its potential contribution to the food supply of Rome. This analysis showed which models could adequately supply urban centres and which were inadequate (Table 8.25, page 382). This model also showed that the most stable supply model, once again, was that of intercropping, which could generally support an urban population even when wheat yields were low.

If we accept the assumption that a high population density was likely near the urban metropolis of Rome, these models may be used to ascertain which variables were more likely than others. For example, we may argue that arable yields were likely to have been in the region of 8-15:1 and that a large proportion of the land was cultivated, given the density of settlement. We have by no means recovered all the Early Imperial sites in the study area, so we cannot know the full extent of this. We cannot assume that the recovery rate is as postulated by Cambi (1999: 121), but models such as this may be carried out on a number of recovery rates in order to gauge the effects on the population figures. If more sites were exploited in antiquity then consequently population density and surplus production would have been higher, assuming that there was sufficient high-yielding land remaining unexploited in the study area. The population could, however, only grow to a certain point before all the high quality land was under cultivation. The more marginal lands would have produced lower yields and subsequently the supported population would not increase in a linear fashion with agricultural exploitation.

Some historians have argued that cereal cultivation was in crisis in the late 1st century AD due to competition with cash crops such as vines (Chapter 2.1.2). However, it could be argued that, if this crisis occurred at all, it was an elite and urban problem rather than one affecting the vast majority of rural producers. One could argue that the crisis was an economic rather than a productive one, as rural producers would not have neglected to grow enough to feed themselves unless either adversely affected by environmental factors or forced to part with their produce as rents for elite landowners. The models presented show to a certain extent, however, what the effects of such a crisis could have been. Regarding the implications of the agronomists, it has been shown that Varro's model (a maximum 15:1 yield) implies a thriving area, fully able to support large local urban populations, and still provide a large surplus for Rome. Columella's 4:1 yield within a monocultural system, however, produces dangerously low returns and consequently Early Imperial towns must have been in decline unless they were able to provide a significant service function to engage in longer-distance trade. This extreme model is implausible and so, as suggested by scholars (e.g. White 1963: 209), Columella's yield is more likely to have referred to an intercultivation system. If intercultivation is assumed, the picture is far less severe and again may support a considerable urban population, though longer distance exports to Rome were less likely than with Varro's model.

As stated at the beginning of this chapter, only a few of these models can be considered 'likely scenarios' for the Early Imperial period. Taking into consideration all the evidence presented above, the most likely models are quarter-fallowed intercropping models at a reasonably high rate of production: this would have allowed a reasonable rate of urban development and have guarded against serious food shortages. The surplus models showed that low yields could have easily caused problems for urban populations and that crop failures on a more serious level could have been catastrophic. The fact that most towns continued to prosper in this period would imply that both Varro and Columella's models (assuming intercultivation for the latter) could both have been plausible systems for the study area, despite at first appearing to show conflicting situations. If production was lower than the agronomists suggested, or local production faltered due to crop failures, then longer-distance trade networks must have been able to supply sufficient food to continue the support of non-agriculturally productive citizens and avoid serious food shortages.

Using known sites only, the population density of the study area is initially estimated to be 16-34 people/km^2 (18 people/km^2 on average), assuming a yield of 8-15:1 intercropping model with one-quarter fallow, which would increase with the addition of animals. However, this density increases to 23-90 people/km^2 (with a mean of 48 people/km^2) with the modelling of sample sites to fill in survey gaps. This latter model is considered here to reflect the most likely scenario in this area, and as such shows more affinity with the higher estimates of population density put forward by Lo Cascio (1994) than the lower estimates of scholars such as Beloch and Brunt (Beloch 1886: chap. 8, in Lo Cascio 1999: 162; Brunt 1971a: 124ff). This is made more so when we consider the calorific addition made by wine (Chapter 8.3.3) which could vastly increase the supported population with high yields.

Additionally, it must be remembered that the only sites being modelled are 12 *iugera* farms and 100 *iugera* villas. For the known sites this means that only 7% of the total study area is under cultivation. This increases to 21% with the sample sites, but this is still not a substantial exploitation of the available resources. Although not all the land was suitable for cultivation (for example lake areas, mountains, poor probable soil fertility), this cultivated area could have been significantly increased in order to increase production and consequently have supported an even higher population. Though it was noted that 100 *iugera* was an appropriate upper limit for villa size due to the proximity of sites through field survey, farms larger than 12 *iugera* could potentially be modelled. Though outside the scope of this particular study, it is not difficult to imagine the difference that could be made by farms of a larger size.

Whilst these conclusions appear to point to a very high population density for this area, it must be remembered that we are dealing with a unique area which is extremely unlikely to reflect conditions elsewhere on the peninsula. We may therefore only identify with the high counters if it is assumed that all of Italy was as densely populated as the periphery of Rome. It has already been shown in Chapter 3 that, even within the study area, the density of settlement decreases with distance to the capital and this, combined with the variety of agricultural productivity across the country, would result in a differentially dispersed population. We must therefore accept a lowering of the overall population density to ensure parity with the conditions of the previous demographic estimates. This would imply that, far from identifying with either high or low counters, a middle range between the two extremes actually appears more likely.

I would argue, however, that overall densities for the country – whilst enabling comparison to other demographic studies – are less meaningful than regional analysis of settlement and production. To follow from this, the modelling described in this thesis could be developed further in this respect. Chapter 3 showed there was significant regional difference in settlement distribution, and therefore potential farm and estate size. Further smaller-scale models could be carried out to investigate regional production in estates of different sizes rather than generalising models of the entire study area which disguise the inherent variety in agricultural production.

To conclude, a methodology has been presented here for evaluating potential production based on a combination of sources. Although, as we have seen, this was not without its own problems of interpretation, this type of analysis will hopefully complement previous studies of location and demography, which have been mostly hypothetical estimates and generally not based on an assessment of potential land quality in specific regions. By assessing potential production, we can see how productive farms and estates could have been, as well as how the urban structures may have been supported by their surplus. The productive capacity of certain sites can also give an insight into their potential use, whether it was more likely they cultivated cereals, olives or vines. Such a model may be adapted for use for any type of crop or economy, assuming the raw data is available for input, and may be applied to any region or period. These models therefore provide a means of quantification for agricultural production, a fundamental factor that supports all societies, ancient and modern.

Appendix I. Full transcription of the *Menologium Rusticum Colotianum*

CIL VI 2305 = *ILS* 8745 (translation by Lewis and Reinhold 1990: 213-214)

ILS 8745, 1	
MENSIS IANVAR	Month of January
DIES XXXI	31 days
NON QVINT	The Nones fall on the fifth day
DIES HOR VIIIIS .	The day has 9 3/4 hours
NOX HOR XIIII .	The night has 14 1/4 hours
SOL CAPRICORNO	The sun is in the sign of Capricorn
TVTELA IVNONIS	The month is under the protection of Juno
PALVS AQVITVR	Stakes are sharpened
SALIX HARVNDO CAEDITVR	Willow and reeds are cut
SACRIFICANT DIS PENATIBVS	Sacrifices to the household gods

ILS 8745, 2	
MENSIS FEBRVAR	Month of February
DIES XXVIII	28 days
NON QVINT	The Nones fall on the fifth day
DIES HOR XS .	The day has 10 3/4 hours
NOX HOR XIII .	The night has 13 1/4 hours
SOL AQVARIO	The sun is in the sign of Aquarius
TVTEL NEPTVNI	The month is under the protection of Neptune
SEGETES SARIVNTVR	The grain fields are weeded
VINEARVM SVPERFIC COLIT	The part of the vines above ground is tended
HARVNDINES INCENDVNT	Reeds are burned
PARENTALIA	Parentalia
LVPERCALIA	Lupercalia
CARA COGNATIO	Dear Relative's Day
TERMINALIA	Terminalia

ILS 8745, 3

MENSIS	Month of March
MARTIVS	
DIES XXXI	31 days
NON SEPTIMAN	The Nones fall on the seventh day
DIES HOR XII	The day has 12 hours
NOX HOR XII	The night has 12 hours
AEQVINOCTIVM	The equinox falls on the twenty-fifth day
VIII KAL APR	
SOL PISCIBVS	The sun is in the sign of Pisces
TVTEL MINERVAE	The month is under the protection of Minerva
VINEAE PEDAMIN	The vines are propped up in trenched ground and pruned
IN PASTINO	
PVTANTVR	Three month wheat is sown
TRIMESTR SERITVR	The bark of Isis
ISIDIS NAVIGIVM	Sacrifices to Mamurius
SACR MAMVRIO	Liberalia, Quinquatria
LIBERAL QVINQVATRIA	Bathing
LAVATIO	

ILS 8745, 4

MENSIS	Month of April
APRILIS	
DIES XXX	30 days
NONAE	The Nones fall on the fifth day
QVINTAN	
DIES	The day has 13 1/2 hours
HOR XIIIS	
NOX	The night has 10 1/2 hours
HOR XS	
SOL ARIETE	The sun is in the sign of Aries
TVTELA	The month is under the protection of Venus
VENERIS	
OVES	The lustration of the sheep is made
LVSTRANTVR	
SACRVM	
PHARIAE	Sacrifices to the Isis of Pharus
ITEM	
SARAPIA	Also festival of Sarapis

ILS 8745, 5

MENSIS	Month of May
MAIVS	
DIES XXXI	31 days
NON SEPTIM	The Nones fall on the seventh day
DIES HOR XIIIIS	The day has 14 1/2 hours
NOX HOR VIIIIS	The night has 9 1/2 hours
SOL TAVRO	The sun is in the sign of Taurus
TVTEL APOLLIN	The month is under the protection of Apollo
SEGET RVNCANT	The grain fields are cleared of weeds
OVES TVNDVNT	The sheep are shorn
LANA LAVATVR	The wool is washed
IVVENCI DOMANT	Young steers are put under the yoke
VICEA PABVLAR	
SECATVR	The vetch for fodder is cut
SEGETES	
LVSTRANTVR	The lustration of the grain fields is made
SACRVM MERCVR	Sacrifices to Mercury and Flora
ET FLORAE	

ILS 8745, 6	
MENSIS	Month of June
IVNIVS	
DIES XXX	30 days
NON QVINT	The Nones fall on the fifth day
DIES HOR XV	The day has 15 hours
NOX HOR VIIII	The night has 9 hours
SOLIS INSTITIVM	The solstice falls on the twenty-fourth day
VIII KAL IVL	
SOL GEMINIS	The sun is in the sign of Gemini
TVTELA	The month is under the protection of Mercury
MERCVRI	
FAENISICIVM	The hay is mown
VINIAE	The vines are cultivated
OCCANTVR	
SACRVM	Sacrifice to Hercules and Fors Fortuna
HERCVLI	
FORTIS	
FORTVNAE	

ILS 8745, 7	
MENSIS	Month of July
IVLIVS	
DIES XXXI	31 days
NONAE	The Nones fall on the seventh day
SEPTIMAN	
DIES	The day has 14 1/4 hours
HORARVM	
XIIII .	
NOX HOR	The night has 9 3/4 hours
VIIIIS .	
SOL CANCR	The sun is in the sign of Cancer
TVTELA	The month is under the protection of Jupiter
IOVIS	
MESSES	Barley and beans are harvested
HORDIAR	
ET FABAR	
APOLLINAR	Apollinaria
NEPTVNAL	Neptunalia

ILS 8745, 8	
MENSIS	Month of August
AVGVST	
DIES XXXI	31 days
NON QVINT	The Nones fall on the fifth day
DIES HOR XIII	The day has 13 hours
NOX HOR XI	The night has 11 hours
SOL LEONE	The sun is in the sign of Leo
TVTEL CERER	The month is under the protection of Ceres
PALVS PARAT	The stakes are prepared
MESSES	Cereals are harvested,
FRVMENTAR	
ITEM	likewise the wheat
TRITICAR	
STVPVLAE	The stubble is burned
INCENDVNT	
SACRVM SPEI	Sacrifices to Hope, Safety, and Diana
SALVTI DEANAE	
VOLCANALIA	Volcanalia

ILS 8745, 9	
MENSIS	Month of September
SEPTEMBER	
DIES XXX	30 days
NON QVINT	The Nones fall on the fifth day
DIES HOR XII	The day has 12 hours
NOX HOR XII	The night has 12 hours
AEQVINOCT	The equinox falls on the twenty-fourth day
VIII KAL OCT	
SOL VIRGINE	The sun is in the sign of Virgo
TVTELA	The month is under the protection of Vulcan
VOLCANI	
DOLEA	The casks are smeared with pitch
PICANTVR	
POMA LEGVNT	Fruits are gathered
ARBORVM	The earth around the trees is dug up
OBLAQVIATIO	
EPVLVM	Feast of Minerva
MINERVAE	

ILS 8745, 10	
MENSIS	Month of October
OCTOBER	
DIES XXXI	31 days
NONAE	The Nones fall on the seventh day
SEPTIMAN	
DIES	The day has 10 3/4 hours
HOR XS .	
NOX	The night has 13 1/4 hours
HOR XIII .	
SOL	The sun is in the sign of Libra
LIBRA	
TVTELA	The month is under the protection of Mars
MARTIS	
VINDEMIAE	Grape gathering
SACRVM	Sacrifices to Bacchus
LIBERO	

ILS 8745, 11	
MENSIS	Month of November
NOVEMBER	
DIES XXX	30 days
NON QVINT	The Nones fall on the fifth day
DIES HOR VIIIIS	The day has 9 1/2 hours
NOX HOR XIIIIS	The night has 14 1/2 hours
SOL	The sun is in the sign of Scorpio
SCORPIONE	
TVTELA	The month is under the protection of Diana
DEANAE	
SEMENTES	Sowing of wheat and barley
TRITICARIAE	
ET HORDIAR	
SCROBATIO	Digging of trenches for trees
ARBORVM	
IOVIS	Feast of Jupiter
EPVLVM	Discovery [a festival of Osiris]
HEVRESIS	

ILS 8745, 12	
MENSIS DECEMB	Month of December
DIES XXXI	31 days
NON QVINT	The Nones fall on the fifth day
DIES HOR VIIII	The day has 9 hours
NOX HOR XV	The night has 15 hours
SOL SAGITT	The sun is in the sign of Sagittarius
TVTEL VESTAE	The month is under the protection of Vesta
HIEMPS INITIV SIVE TROPAE CHIMERIN	Beginning of winter, or winter solstice
VINEAS STERC	The vines are manured
FABA SERENTES	Beans are sown
MATERIAS DEICIENTES	Wood is cut
OLIVA LEGENT ITEM VENANT	Olives are gathered and also sold
SATVRNALIA	Saturnalia

Appendix II. Tables showing site sizes from Chapter 3

Table II.1 Number of Early Imperial sites in different size categories from Thiessen territories

No. of *iugera*	No. of sites
0-10	0
10-20	1
20-30	5
30-40	8
40-50	11
50-60	20
60-70	27
70-80	31
80-90	37
90-100	48
100-150	197
150-200	168
200-250	90
250-300	76
300-400	99
400-500	65
500+	291

MIN	17 *iugera*
MEAN	479 *iugera*
MAX	12,558 *iugera*

Table II.2 Number of Early Imperial sites in different size categories from circular territories

No. of *iugera*	No. of farms	No. of villas
0-10	24	14
10-20	41	40
20-30	67	59
30-40	74	84
40-50	37	57
50-60	65	69
60-70	15	19
70-80	23	32
80-90	12	25
90-100	10	24
100-150	54	68
150-200	16	33
200-250	22	27
250-300	8	21
300-400	12	25
400-500	6	6
500+	12	22

	Farms	Villas
MIN	2 *iugera*	3 *iugera*
MEAN	126 *iugera*	139 *iugera*
MAX	14,026 *iugera*	7,264 *iugera*

Appendix III. Full tables and equations for locational analysis, Chapter 4

Table III.1 Observed (O) and expected (E) numbers of Late Republican farms compared to aspect

	No of sites	Expected	(O-E)	$(O-E)^2$	$(O-E)^2/E$	
Flat	6	9.21	-3.21	10.28	1.12	
N	10	15.13	-5.13	26.36	1.74	
NE	11	20.10	-9.10	82.77	4.12	
E	29	22.73	6.27	39.27	1.73	
SE	18	22.05	-4.05	16.39	0.74	
S	25	18.68	6.32	39.96	2.14	
SW	27	18.57	8.43	71.08	3.83	
W	19	17.40	1.60	2.56	0.15	
NW	13	14.13	-1.13	1.28	0.09	$\chi^2 =$ 15.65

Table III.2 Observed (O) and expected (E) numbers of Late Republican villas compared to aspect

	No of sites	Expected	(O-E)	$(O-E)^2$	$(O-E)^2/E$	
Flat	10	18.30	-8.30	68.85	3.76	
N	22	30.08	-8.08	65.23	2.17	
NE	35	39.94	-4.94	24.42	0.61	
E	39	45.18	-6.18	38.18	0.85	
SE	51	43.82	7.18	51.57	1.18	
S	46	37.12	8.88	78.85	2.12	
SW	44	36.90	7.10	50.37	1.36	
W	38	34.58	3.42	11.70	0.34	
NW	29	28.08	0.92	0.84	0.03	$\chi^2 =$ 12.42

Table III.3 Observed (O) and expected (E) numbers of Early Imperial farms compared to aspect

	No of sites	Expected	(O-E)	$(O-E)^2$	$(O-E)^2/E$	
Flat	20	33.10	-13.10	171.57	5.18	
N	36	54.41	-18.41	338.77	6.23	
NE	66	72.25	-6.25	39.08	0.54	
E	96	81.73	14.27	203.76	2.49	
SE	86	79.26	6.74	45.36	0.57	
S	80	67.15	12.85	165.19	2.46	
SW	75	66.75	8.25	68.00	1.02	
W	60	62.55	-2.55	6.51	0.10	
NW	49	50.80	-1.80	3.25	0.06	$\chi^2 =$ 18.66

Table III.4 Observed (O) and expected (E) numbers of Early Imperial villas compared to aspect

	No of sites	Expected	(O-E)	$(O-E)^2$	$(O-E)^2/E$	
Flat	17	40.50	-23.50	552.21	13.64	
N	51	66.57	-15.57	242.43	3.64	
NE	74	88.41	-14.41	207.53	2.35	
E	94	100.00	-6.00	35.99	0.36	
SE	115	96.99	18.01	324.44	3.35	
S	101	82.16	18.84	354.92	4.32	
SW	99	81.68	17.32	300.00	3.67	
W	86	76.54	9.46	89.56	1.17	
NW	58	62.16	-4.16	17.32	0.28	$\chi^2 = 32.77$

Table III.5 Translations of geology

ID	Original Italian description	Translation
1	Alluvioni attuali e recenti.	Quaternary and recent alluvium
2	Argille e marne grigio-azzurre.	Grey-blue clays and marls
3	Alluvioni fluviali.	Fluvial deposits
4	Arenarie con sporadiche intercalazioni di argille e marne.	Sandstones with sporadic inclusions of clays and marls
5	Calcareniti, brecciole calcaree organogene.	Calcareous sandstones, small organic shell fragments
6	Conglomerati e brecce cementate, brecce di pendio.	Conglomerates and cemented rubble (breccias), scree (breccias on slopes)
7	Calcari micritici, detritici e calcareniti	Micritic limestones and calcareous sandstones
8	Calcari micritici compatti con selce, calcari marnosi e marne	Micritic compacted limestones with cherts, marly limestones and marls
9	Cineriti più o meno limose	Bedded tuff (layered ash deposit) with variable silt content
10	Dolomie cristalline e dolomie calcaree	Crystalline dolomites and calcareous dolomites
11	Diaspri straterellati, calcari marnosi e argillosi	Bedded jasper, marly limestones and clayey limestones
12	Detriti di falda, sciolti e debolmente cementati	Nappe debris, weakly or not cemented
13	Sedimenti limno-palustri e fluvio-lacustri prevalentemente argillosi	Loam sediment (deposited in swamps) and fluvial loams, mainly clay
14	Colate laviche	Lava flows
15	laghi	lakes
16	Sabbie e limi lacustri-salmastri	Sands and lacustrine/brackish lagoon silts
17	Alternanza di arenarie marnose e marne argillose	Marly clays and marls with sandsatones interbedded
18	Marne con intercalazioni calcaree	Marl with calcareous intercalations
19	Argille, argille marnose e marne con alternanze di arenarie.	Marly clay, clay and marls with sandstone alternations
20	Sabbie gialle e sabbioni grossolani concrezionati.	Yellow sands and coarser sands cemented
21	Sabbie talvolta concrezionate.	Sands, often with concretions
22	Sabbie da spiaggia, da fini a grossolane.	Beach sands, fine to coarse
23	Terre nere umifere argillose.	Clayey black soils, rich in humus
24	Travertini da litoidi a terrosi.	Travertine, more or less clayey
25	Aree urbane	Urban areas
26	Tufi, pozzolane, ignimbriti	Tuff, pozzolana and ignimbrites

Table III.6 Observed (O) and expected (E) arable land use compared to geology

Geology Description	Area	Modern arable	%	Expected	(O-E)	$(O-E)^2$	$(O-E)^2/E$
Tuff, pozzolana and ignimbrites	11,1587.4	493,127	56.88	407,518	85,609	7,328,885,191	17,984
Quaternary and recent alluvium	23,636.34	166,073	19.16	86,320	79,753	6,360,524,139	73,685
Fluvial deposits	3,747.24	23,246	2.68	13,685	9,561	91,413,659	6,680
Travertine, more or less clayey	3,567.96	20,173	2.33	13,030	7,143	51,019,322	3,915
Clayey black soils, rich in humus	1,424.88	11,183	1.29	5,204	5,979	35,752,347	6,871
Lava flows	8,730	36,519	4.21	31,882	4,637	21,501,482	674
Sandstones with sporadic inclusions of clays and marls	324.72	2,414	0.28	1,186	1,228	1,508,279	1,272
Sands and lacustrine/brackish lagoon silts	130.32	690	0.08	476	214	45,826	96
Urban areas	4,714.38	17,417	2.01	17,217	200	40,018	2
Grey-blue clays and marls	112.05	514	0.06	409	105	10,981	27
Marly clay, clay and marls with sandstone alternations	119.88	447	0.05	438	9	85	0
Marly clays and marls with sandsatones interbedded	23.58	62	0.01	86	-24	582	7
Calcareous sandstones, small organic shell fragments	207	673	0.08	756	-83	6,883	9
Crystalline dolomites and calcareous dolomites	128.88	176	0.02	471	-295	86,831	184
Conglomerates and cemented rubble (breccias), scree (breccias on slopes)	182.79	141	0.02	668	-527	277,255	415
Beach sands, fine to coarse	222.48	0		812	-812	660,154	812
Bedded jasper, marly limestones and clayey limestones	270.45	111	0.01	988	-877	768,578	778
Bedded tuff (layered ash deposit) with variable silt content	330.66	261	0.03	1,208	-947	896,000	742
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	1,963.17	4,958	0.57	7,170	-2,212	4,890,789	682
Yellow sands and coarser sands cemented	1,415.34	1,195	0.14	5,169	-3,974	15,791,350	3,055
Nappe debris, weakly or not cemented	2,022.84	1,636	0.19	7,387	-5,751	33,078,925	4,478
Marl with calcareous intercalations	4,346.1	4,423	0.51	15,872	-11,449	131,079,430	8,259
Micritic compacted limestones with cherts, marly limestones and marls	7,650.45	2,306	0.27	27,940	-25,634	657,076,608	23,518
lakes	7,223.67	655	0.08	26,381	-25,726	661,822,010	25,087
Micritic limestones and calcareous sandstones	8,017.65	1,145	0.13	29,281	-28,136	791,607,652	27,035
Sands, often with concretions	45,250.83	77,263	8.91	165,256	-87,993	7,742,838,250	46,853
TOTAL	237,351.06	866,808		866,808		χ^2 =	253,123

Table III.7 Observed (O) and expected (E) olive land use compared to geology

Geology Description	Area	Modern olives	%	Expected	(O-E)	$(O-E)^2$	$(O-E)^2/E$
Sands, often with concretions	45,250.83	141,453.00	48.78	55,240.08	86,212.92	7,432,667,068.20	134,552.06
Marl with calcareous intercalations	4,346.10	10,652.00	3.67	5,305.51	5,346.49	28,584,909.62	5,387.77
Micritic limestones and calcareous sandstones	8,017.65	14,263.00	4.92	9,787.57	4,475.43	20,029,476.69	2,046.42
Yellow sands and coarser sands cemented	1,415.34	4,799.00	1.65	1,727.78	3,071.22	9,432,389.58	5,459.25
Nappe debris, weakly or not cemented	2,022.84	5,327.00	1.84	2,469.39	2,857.61	8,165,947.25	3,306.87
Fluvial deposits	3,747.24	6,514.00	2.25	4,574.45	1,939.55	3,761,837.99	822.36
Bedded tuff (layered ash deposit) with variable silt content	330.66	1,895.00	0.65	403.65	1,491.35	2,224,112.41	5,509.95
Conglomerates and cemented rubble (breccias), scree (breccias on slopes)	182.79	597.00	0.21	223.14	373.86	139,770.23	626.38
Crystalline dolomites and calcareous dolomites	128.88	372.00	0.13	157.33	214.67	46,082.94	292.91
Bedded jasper, marly limestones and clayey limestones	270.45	311.00	0.11	330.15	-19.15	366.82	1.11
Marly clays and marls with sandsatones interbedded	23.58	0.00		28.79	-28.79	828.60	28.79
Grey-blue clays and marls	112.05	0.00		136.79	-136.79	18,710.24	136.79
Marly clay, clay and marls with sandstone alternations	119.88	0.00		146.34	-146.34	21,416.53	146.34
Sands and lacustrine/brackish lagoon silts	130.32	0.00		159.09	-159.09	25,309.16	159.09
Calcareous sandstones, small organic shell fragments	207.00	0.00		252.70	-252.70	63,855.20	252.70
Beach sands, fine to coarse	222.48	0.00		271.59	-271.59	73,762.82	271.59
Travertine, more or less clayey	3,567.96	4,044.00	1.39	4,355.60	-311.60	97,093.06	22.29
Sandstones with sporadic inclusions of clays and marls	324.72	51.00	0.02	396.40	-345.40	119,303.16	300.96
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	1,963.17	2,000.00	0.69	2,396.55	-396.55	157,248.34	65.61
Clayey black soils, rich in humus	1,424.88	458.00	0.16	1,739.43	-1,281.43	1,642,053.68	944.02
Micritic compacted limestones with cherts, marly limestones and marls	7,650.45	7,217.00	2.49	9,339.31	-2,122.31	4,504,196.30	482.28
Urban areas	4,714.38	0.00		5,755.09	-5,755.09	33,121,097.28	5,755.09
lakes	7,223.67	0.00		8,818.32	-8,818.32	77,762,701.64	8,818.32
Lava flows	8,730.00	1,344.00	0.46	10,657.17	-9,313.17	86,735,191.47	8,138.67
Quaternary and recent alluvium	23,636.34	9,809.00	3.38	28,854.13	-19,045.13	362,717,019.26	12,570.71
Tuff, pozzolana and ignimbrites	111,587.40	78,641.00	27.12	136,220.64	-57,579.64	3,315,415,471.34	24,338.57
TOTAL	237,351.06	866,808		866,808		χ^2 =	253,123

Table III.8 Observed (O) and expected (E) numbers of all Late Republican farms compared to geology

Geology Description	Area	LR sites	%	Exp	O-E	$(O-E)^2$	$(O-E)^2/E$
Tuff, pozzolana and ignimbrites	82,980.99	35.04	123	49.06	73.94	5,467.60	111.45
Calcareous sandstones, small organic shell fragments	207	0.09	2	0.12	1.88	3.53	28.81
Urban areas	2,037.33	0.86	2	1.20	0.80	0.63	0.53
Yellow sands and coarser sands cemented	576.45	0.24	1	0.34	0.66	0.43	1.28
Travertine, more or less clayey	2,369.88	1.00	2	1.40	0.60	0.36	0.26
Grey-blue clays and marls	17.46	0.01	0	0.01	-0.01	0.00	0.01
Bedded jasper, marly limestones and clayey limestones	21.69	0.01	0	0.01	-0.01	0.00	0.01
Marl with calcareous intercalations	32.31	0.01	0	0.02	-0.02	0.00	0.02
Marly clay, clay and marls with sandstone alternations	47.16	0.02	0	0.03	-0.03	0.00	0.03
Crystalline dolomites and calcareous dolomites	52.47	0.02	0	0.03	-0.03	0.00	0.03
Sands and lacustrine/brackish lagoon silts	54.27	0.02	0	0.03	-0.03	0.00	0.03
Beach sands, fine to coarse	68.85	0.03	0	0.04	-0.04	0.00	0.04
lakes	128.97	0.05	0	0.08	-0.08	0.01	0.08
Sandstones with sporadic inclusions of clays and marls	314.1	0.13	0	0.19	-0.19	0.03	0.19
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	387.45	0.16	0	0.23	-0.23	0.05	0.23
Micritic compacted limestones with cherts, marly limestones and marls	454.14	0.19	0	0.27	-0.27	0.07	0.27
Nappe debris, weakly or not cemented	548.73	0.23	0	0.32	-0.32	0.11	0.32
Clayey black soils, rich in humus	992.7	0.42	0	0.59	-0.59	0.34	0.59
Micritic limestones and calcareous sandstones	1,026.54	0.43	0	0.61	-0.61	0.37	0.61
Fluvial deposits	2,243.25	0.95	0	1.33	-1.33	1.76	1.33
Lava flows	4,369.05	1.84	1	2.58	-1.58	2.51	0.97
Sands, often with concretions	18,236.16	7.70	6	10.78	-4.78	22.86	2.12
Quaternary and recent alluvium	15,042.06	6.35	3	8.89	-5.89	34.72	3.90
TOTAL	132,209		140	78.15949		$\chi^2 =$	153.09

Table III.9 Observed (O) and expected (E) numbers of all Late Republican villas compared to geology

Geology Description	Area	LR sites	%	Exp	O-E	$(O-E)^2$	$(O-E)^2/E$
Tuff, pozzolana and ignimbrites	111587.4	47.12	214	129.58	84.42	7126.61	55.00
Urban areas	4714.38	1.99	12	5.47	6.53	42.58	7.78
Fluvial deposits	3747.24	1.58	7	4.35	2.65	7.01	1.61
Crystalline dolomites and calcareous dolomites	128.88	0.05	2	0.15	1.85	3.42	22.88
Calcareous sandstones, small organic shell fragments	207	0.09	1	0.24	0.76	0.58	2.40
Grey-blue clays and marls	112.05	0.05	0	0.13	-0.13	0.02	0.13
Marly clay, clay and marls with sandstone alternations	119.88	0.05	0	0.14	-0.14	0.02	0.14
Sands and lacustrine/brackish lagoon silts	130.32	0.06	0	0.15	-0.15	0.02	0.15
Beach sands, fine to coarse	222.48	0.09	0	0.26	-0.26	0.07	0.26
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	1963.17	0.83	2	2.28	-0.28	0.08	0.03
Bedded jasper, marly limestones and clayey limestones	270.45	0.11	0	0.31	-0.31	0.10	0.31
Sandstones with sporadic inclusions of clays and marls	324.72	0.14	0	0.38	-0.38	0.14	0.38
Yellow sands and coarser sands cemented	1415.34	0.60	1	1.64	-0.64	0.41	0.25
Clayey black soils, rich in humus	1424.88	0.60	0	1.65	-1.65	2.74	1.65
Travertine, more or less clayey	3567.96	1.51	2	4.14	-2.14	4.59	1.11
Nappe debris, weakly or not cemented	2022.84	0.85	0	2.35	-2.35	5.52	2.35
Marl with calcareous intercalations	4346.1	1.84	0	5.05	-5.05	25.47	5.05
Lava flows	8730	3.69	4	10.14	-6.14	37.67	3.72
lakes	7223.67	3.05	0	8.39	-8.39	70.37	8.39
Micritic compacted limestones with cherts, marly limestones and marls	7650.45	3.23	0	8.88	-8.88	78.93	8.88
Micritic limestones and calcareous sandstones	8017.65	3.39	0	9.31	-9.31	86.69	9.31
Quaternary and recent alluvium	23636.34	9.98	9	27.45	-18.45	340.32	12.40
Sands, often with concretions	45250.83	19.11	21	52.55	-31.55	995.24	18.94
TOTAL	236814		275	275		χ^2 =	163.12

Table III.10 Observed (O) and expected (E) numbers of all Early Imperial farms compared to geology

Geology Description	Area	LR sites	%	Exp	O-E	$(O\text{-}E)^2$	$(O\text{-}E)^2/E$
Tuff, pozzolana and ignimbrites	11,1587.4	47.12	453	246.44	206.56	42,667.44	173.14
Sandstones with sporadic inclusions of clays and marls	324.72	0.14	4	0.72	3.28	10.78	15.03
Calcareous sandstones, small organic shell fragments	207	0.09	2	0.46	1.54	2.38	5.21
Yellow sands and coarser sands cemented	1,415.34	0.60	4	3.13	0.87	0.76	0.24
Marly clay, clay and marls with sandstone alternations	119.88	0.05	1	0.26	0.74	0.54	2.04
Grey-blue clays and marls	112.05	0.05	0	0.25	-0.25	0.06	0.25
Fluvial deposits	3,747.24	1.58	8	8.28	-0.28	0.08	0.01
Crystalline dolomites and calcareous dolomites	128.88	0.05	0	0.28	-0.28	0.08	0.28
Sands and lacustrine/brackish lagoon silts	130.32	0.06	0	0.29	-0.29	0.08	0.29
Beach sands, fine to coarse	222.48	0.09	0	0.49	-0.49	0.24	0.49
Bedded jasper, marly limestones and clayey limestones	270.45	0.11	0	0.60	-0.60	0.36	0.60
Travertine, more or less clayey	3,567.96	1.51	6	7.88	-1.88	3.53	0.45
Urban areas	4,714.38	1.99	8	10.41	-2.41	5.82	0.56
Clayey black soils, rich in humus	1,424.88	0.60	0	3.15	-3.15	9.90	3.15
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	1,963.17	0.83	1	4.34	-3.34	11.13	2.57
Nappe debris, weakly or not cemented	2,022.84	0.85	0	4.47	-4.47	19.96	4.47
Lava flows	8730	3.69	10	19.28	-9.28	86.12	4.47
Marl with calcareous intercalations	4,346.1	1.84	0	9.60	-9.60	92.13	9.60
Micritic compacted limestones with cherts, marly limestones and marls	7,650.45	3.23	1	16.90	-15.90	252.68	14.96
lakes	7,223.67	3.05	0	15.95	-15.95	254.51	15.95
Micritic limestones and calcareous sandstones	8,017.65	3.39	0	17.71	-17.71	313.53	17.71
Quaternary and recent alluvium	23,636.34	9.98	12	52.20	-40.20	1,616.08	30.96
Sands, often with concretions	45,250.83	19.11	13	99.94	-86.94	7,557.82	75.63
TOTAL	236814		523	523.0001		χ^2 =	378.03

Table III.11 Observed (O) and expected (E) numbers of all Early Imperial villas compared to geology

Geology Description	Area	LR sites	%	Exp	O-E	$(O-E)^2$	$(O-E)^2/E$
Tuff, pozzolana and ignimbrites	111,587.40	47.12	488	298.27	189.73	35,996.97	120.69
Urban areas	4,714.38	1.99	21	12.60	8.40	70.54	5.60
Fluvial deposits	3,747.24	1.58	14	10.02	3.98	15.87	1.58
Travertine, more or less clayey	3,567.96	1.51	13	9.54	3.46	11.99	1.26
Calcareous sandstones, small organic shell fragments	207.00	0.09	3	0.55	2.45	5.99	10.82
Crystalline dolomites and calcareous dolomites	128.88	0.05	2	0.34	1.66	2.74	7.96
Sands and lacustrine/brackish lagoon silts	130.32	0.06	1	0.35	0.65	0.42	1.22
Sandstones with sporadic inclusions of clays and marls	324.72	0.14	1	0.87	0.13	0.02	0.02
Grey-blue clays and marls	112.05	0.05	0	0.30	-0.30	0.09	0.30
Marly clay, clay and marls with sandstone alternations	119.88	0.05	0	0.32	-0.32	0.10	0.32
Beach sands, fine to coarse	222.48	0.09	0	0.59	-0.59	0.35	0.59
Bedded jasper, marly limestones and clayey limestones	270.45	0.11	0	0.72	-0.72	0.52	0.72
Yellow sands and coarser sands cemented	1,415.34	0.60	1	3.78	-2.78	7.75	2.05
Clayey black soils, rich in humus	1,424.88	0.60	1	3.81	-2.81	7.89	2.07
Loam sediment (deposited in swamps) and fluvial loams, mainly clay	1,963.17	0.83	2	5.25	-3.25	10.55	2.01
Nappe debris, weakly or not cemented	2,022.84	0.85	1	5.41	-4.41	19.42	3.59
Marl with calcareous intercalations	4,346.10	1.84	0	11.62	-11.62	134.96	11.62
Lava flows	8,730.00	3.69	10	23.34	-13.34	177.83	7.62
lakes	7,223.67	3.05	0	19.31	-19.31	372.83	19.31
Micritic limestones and calcareous sandstones	8,017.65	3.39	1	21.43	-20.43	417.43	19.48
Micritic compacted limestones with cherts, marly limestones and marls	7,650.45	3.23	0	20.45	-20.45	418.18	20.45
Quaternary and recent alluvium	23,636.34	9.98	24	63.18	-39.18	1,535.04	24.30
Sands, often with concretions	45,250.83	19.11	50	120.95	-70.95	5,034.57	41.62
TOTAL	236,814		633	633.00		χ^2 =	305.19

Table III.12 Distance of Late Republican and Early Imperial sites from major river systems and lakes

Distance from river in metres	Number of sites in this category			
	LR farms	LR villas	EI farms	EI villas
1-100	11	9	37	27
100-200	13	36	57	85
200-300	24	43	82	93
300-400	24	60	73	111
400-500	14	26	60	63
500-600	16	39	38	68
600-700	9	23	32	51
700-800	9	19	38	37
800-900	7	11	28	24
900-1000	4	11	25	27
1000-1100	11	9	23	27
1100-1200	4	9	16	23
1200-1300	5	4	12	18
1300-1400	2	4	6	13
1400-1500	1	3	15	11
1500-1600	4	5	8	13
1600-1700	1	4	4	10
1700-1800	3	2	6	7
1800-1900	3	2	9	7
1900-2000	1	4	5	7
2000-2100	1	1	5	5
2100-2200	2		8	0
2200-2300		1	1	2
2300-2400	1		2	0
2400-2500		1	1	2
2500-2600			1	0
2600-2700	2		2	1
2700-2800		1	1	1
2800-2900				1
2900-3000			1	

Appendix IV. Classifications for MCE evaluations

Table IV.1 Classification for wheat suitability based on agronomists' recommendations

ID	Geology Description	Calcareous?	Classification
1	Recent and current alluvium	N	255
2	Grey-blue clays and marls	Y	127
3	Fluvial alluvium	N	255
4	Sandstones with sporadic inclusions of clays and marls	partly	127
5	Calcareous sandstones, small organic shell fragments	Y	127
6	Conglomerates and cemented rubble (breccias), scree (breccias on slopes)	N	1
7	Micritic limestones and calcareous sandstones	Y	127
8	Micritic compacted limestones with cherts, marly limestones and marls	Y	127
9	Bedded tuff (layered ash deposit) with variable silt content	N	255
10	Crystalline dolomites and calcareous dolomites	Y	127
11	Bedded jasper, marly limestones and clayey limestones	Y	127
12	Nappe debris, weakly or not cemented	unknown	127
13	Loam sediment (deposited in swamps) and fluvial loams, mainly clay	unknown	127
14	Lava flows	N	255
15	lakes	N	1
16	Sands and lacustrine/brackish lagoon silts	N	127
17	Marly clays and marls with sandsatones interbedded	Y	127
18	Marl with calcareous intercalations?	Y	127
19	Marly clay, clay and marls with sandstone alternations?	Y	127
20	Yellow sands and coarser sands cemented	N	127
21	Sands, often with concretions	N	127
22	Beach sands, fine to coarse	N	127
23	Clayey black soils, rich in humus	N	255
24	Travertine, more or less clayey	Y	127
25	Urban areas	unknown	127
26	Tuff, pozzolana and ignimbrites	N	255

Table IV.2 Classification for olive suitability based on agronomists' recommendations

ID	Geology Description	Calcareous?	Classification
1	Recent and current alluvium	N	1
2	Grey-blue clays and marls	Y	255
3	Fluvial alluvium	N	1
4	Sandstones with sporadic inclusions of clays and marls	partly	255
5	Calcareous sandstones, small organic shell fragments	Y	255
6	Conglomerates and cemented rubble (breccias), scree (breccias on slopes)	N	1
7	Micritic limestones and calcareous sandstones	Y	255
8	Micritic compacted limestones with cherts, marly limestones and marls	Y	255
9	Bedded tuff (layered ash deposit) with variable silt content	N	127
10	Crystalline dolomites and calcareous dolomites	Y	255
11	Bedded jasper, marly limestones and clayey limestones	Y	255
12	Nappe debris, weakly or not cemented	unknown	1
13	Loam sediment (deposited in swamps) and fluvial loams, mainly clay	unknown	1
14	Lava flows	N	127
15	lakes	N	1
16	Sands and lacustrine/brackish lagoon silts	N	1
17	Marly clays and marls with sandstones interbedded	Y	255
18	Marl with calcareous intercalations?	Y	255
19	Marly clay, clay and marls with sandstone alternations?	Y	255
20	Yellow sands and coarser sands cemented	N	127
21	Sands, often with concretions	N	127
22	Beach sands, fine to coarse	N	255
23	Clayey black soils, rich in humus	N	127
24	Travertine, more or less clayey	Y	255
25	Urban areas	unknown	127
26	Tuff, pozzolana and ignimbrites	N	127

Appendix V. Historical yields for Italy and the study area

Table V.1 Historical yields for Italy and the study area

Source	Date	Location	Yield	5 modii per iugerum	6 modii per iugerum	other yield	Notes
ITALY: ANCIENT YIELDS							
Cicero (In Verrem 2.3.112)	70BC	Leontini, Sicily	8 and 10:1	-	1296-1620	-	Sowing rate of 6 modii per iugerum
Varro RR 1.44.1	c.37BC	Etruria	10-15:1	1350-2050	1620-2430	-	
Varro RR 1.44.1	c.37BC	Sybaris	100:1	13500	16200	-	Exceptional but not impossible
See Pliny 18.94-95			100:1				Exceptional
Columella *Rust*. 3.3.4	1st century AD	Italy	4:1	540	648	-	White - Low due to being an arbustum? Spurr p.83 - against idea cf Brunt IM 126ff Playing down idea to promote cash crops?
ITALY: HISTORICAL YIELDS							
V. Fumagalli p.71 (quoted by Spurr p.85)	10th century	Emilia-Romagna - Enzola, in the plain 8km from the Po	3.3+:1	445.5	534.6	-	large monastic domusculta let out in small tenant blocks
V. Fumagalli p.71 (quoted by Spurr p.85)	10th century	Emilia-Romagna - Reggio, on a higher river terrace of the Po	2.8:1	378	453.6	-	large monastic domusculta let out in small tenant blocks
V. Fumagalli p.71 (quoted by Spurr p.85)	10th century	Emilia-Romagna - Vercallo, 3km south of Canossa in the hills	2:1	270	324	-	large monastic domusculta let out in small tenant blocks
V. Fumagalli p.71 (quoted by Spurr p.85)	10th century	Emilia-Romagna - Sciola di Tezzano nel Parmense in the mountains	1.7:1	229.5	275.4	-	large monastic domusculta let out in small tenant blocks
G. Cherubini p.369f quoted by Spurr p.85	1386-90	Tuscany, Arezzo,. Plain of Tregozzano on northern outskirts of Arezzo.	5-11:1 usually 5-7:1	675-945	810-1134	-	Tenant farms (mezzadria) practising biennial fallowing but very few legumes
G. Cherubini p.369f quoted by Spurr p.85	15th-16th centuries	Tuscany, Siena	4-5:1	540-675	648-810	-	Average yield for area
Braudel 1972 p.426 cited by Delano Smith p.196	16th century	Tavoliere of Foggia	15:1				Regarded by Braudel as exceptional
Braudel 1972 p.426 cited by Delano Smith p.196	16th century	Tavoliere of Foggia	20:1				Regarded by Braudel as exceptional

Source	Date	Location	Yield	5 modii per iugerum	6 modii per iugerum	other yield	Notes
G. Cherubini p.369f quoted by Spurr p.85	17th century	Lombardy, Mantua,	5:1	675	810	-	Average yield for area
F. McArdle p.95 quoted by Spurr p.86	17th-18th centuries	Tuscany, Altopascio, - Ducal estate of Altopascio	6.5:1	877.5	1053	-	Comprised 1/3 low yielding hills and 2/3 fertile, reclaimed and drained plain land. Average for two centuries. Estate divided among individual peasant families on the mezzadria system.
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Tuscany, Florence, - "the whole duchy of Florence through"	5-6:1	675-810	810-972	-	
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Tuscany, Florence, - "in the plains"	8:1	1080	1296	-	
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Tuscany, Florence, - "in the deposits of rivers, or spots remarkably rich"	12,15, or even 20:1	1620-2700	1944-3240	-	
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Tuscany, Florence, - "in the low hills overlooking the Arno just upstream from Florence at Villamagna""	9-10:1	1215-1350	1458-1620	-	After legumes - rotation system was legumes, wheat, wheat, wheat with progressively decreasing yields
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Tuscany, Florence, - "in the low hills overlooking the Arno just upstream from Florence at Villamagna""	6-7:1	810-945	972-1134	-	After wheat
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Tuscany, Florence - "in the low hills overlooking the Arno just upstream from Florence at Villamagna""	3-4:1	405-540	486-648	-	After wheat
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Piedmont, - Chentale (Centallo), in the high Piedmont plain with rich sandy loam and coarse gravel	6:1 up to 10-11:1	810-1485	972-1782	-	6:1 yield = normal, 10-11:1 = good
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Piedmont, - Savigliano (as for Chentale)	8:1	1080	1296	-	Described as a good crop
A. Young p.157:209-15 quoted by Spurr p.86	late 18th century	Lombardy, - Codogno, in the well-watered, low plain of the Po, with loamy soils and finer gravel	6:1 up to 12,14,16:1	810-2160	972-2592	-	Lower yield when cultivated with the plough rather than the spade.

Source	Date	Location	Yield	5 modii per iugerum	6 modii per iugerum	other yield	Notes
A. Young p.157:209-15 quoted by Spurr p.87	late 18th century	Veneto, - Verona, vines and grain intercultivated on flat and well-watered loamy soils	5-6:1	675-810	810-972	-	
A. Young p.157:209-15 quoted by Spurr p.87	late 18th century	Veneto, - Padua, as above	less than 7:1 (6.5)	945	1134	-	Poor yields attributed to intercultivation.
Casalis 1833 cited by Delano Smith p.196	1830s	Sardinia, Fonni	401				Wheat. 6:1 for barley. NOTE: Over 900m in altitude and said to be only fit for beans
Casalis 1833 cited by Delano Smith p.196	1830s	Sardinia, Barumini	20:1				For both wheat and barley. Rolling hills.
G. Porisini cited in Ampolo 'Condizioni materiali' p.22, quoted by Spurr p.87	1832-3	Latium, Sora, in the hills above the Sacco river plain	3.14:1-5.2:1	423.9-702	508.68-842.4	-	
G. Porisini cited in Ampolo 'Condizioni materiali' p.22, quoted by Spurr p.87	1832-3	Latium, Gaeta, on the coastal plain	5-7.5:1	675-1012.5	810-1215	-	
de Tournon cited in Ampolo p.22 and Spurr p.87	early 19th century	Latium, - best soils	10:1	1350	1620	-	
de Tournon cited in Ampolo p.22 and Spurr p.87	early 19th century	Latium, - good soils	7:1	945	1134	-	
de Tournon cited in Ampolo p.22 and Spurr p.87	early 19th century	Latium, - medium soils	5:1	675	810	-	
de Tournon cited in Ampolo p.22 and Spurr p.87	early 19th century	Latium, - poor soils	4:1	540	648	-	
Schmidt 1936, Table 3 p.650	1909-14	Central Italy	-	-	-	910	9.1 quintals per hectare
Carcopino cited by Toynbee p.215	1909	Sicily	-	-	-	1686	12 hectolitres per hectare
Rossi Dora p.108-9 quoted by Spurr p.88	1909	Basilicata, Whole region	8:1	-	-	1030	10.3 quintals per hectare
G. Dalmasso p.163 quoted by Spurr p.87	1910	Piedmont, Atigiana, - various soils from sand to heavy clay	c.13-14:1	-	-	1800	Small farms of 3-8 hectares. Legumes rare, cultivation very simple, but limited use of chemical fertiliser - 18 quintals per hectare

Source	Date	Location	Yield	5 modii per iugerum	6 modii per iugerum	other yield	Notes
Rossi Dora p.108-9 quoted by Spurr p.88	1910	Basilicata, Whole region	4:1	-	-	570	5.7 qu per ha
Rossi Dora p.108-9 quoted by Spurr p.88	1911	Basilicata - Whole region	6.5:1	-	-	880	8.8 qu per ha
Rossi Dora p.108-9 quoted by Spurr p.88	1912	Basilicata - Whole region	5:1	-	-	680	6.8 qu per ha
Rossi Dora p.108-9 quoted by Spurr p.88	1913	Basilicata - Whole region	8:1	-	-	1060	10.6 qu per ha
Schmidt 1936, Table 3 p.650	1921-25	Central Italy	-	-	-	990	9.9 quintals per hectare
Schmidt 1936, Table 3 p.650	1926-30	Central Italy	-	-	-	1110	11.1 quintals per hectare
Rossi Dora p.108-9 quoted by Spurr p.88	1930	Basilicata - rocky mountains	5-6:1	-	-	600-800	6-8 qu per ha. Average yields
Rossi Dora p.108-9 quoted by Spurr p.88	1930	Basilicata - pliocene clays	8-9:1	-	-	1000-1200	10-12 qu per ha. Average yields
Rossi Dora p.108-9 quoted by Spurr p.88	1930	Basilicata - average yields for alluvial soils in valleys and coastal plains	9-10:1	-	-	1200-1400	12-14 qu per ha
Schmidt 1936, Table 3 p.650	1931-35	Central Italy	-	-	-	1370	13.7 quintals per hectare
Naval Intelligence Vol III, p.519-523	1938	Rieti	-	-	-	938.00046	41000 metric tonnes for 108000 acres
Naval Intelligence Vol III, p.519-523	1938	Rome	-	-	-	1297.6256	94000 metric tonnes for 72440 acres
S. Van Valkenberg, The Structure of Italian Agriculture , Economic Geography 18(2) 1942 p.109-124 Fig 4 p.114	1942	Lazio	-	-	-	1000-1500	10-15 quintals per hectare
White 1963 p.211	1959	Italy	-	-	-	1800	18 quintals per hectare
Delano Smith p.196	1960s	Tavoliere of Foggia	5-7:1				20-30 quinteax per hectare, under dry farming conditions
FAO	1961	Italy	-	-	-	2181.5	
White 1963 p.211	1963	Sicily	-	-	-	1060	10.6 quintals per hectare
Annuario di statistica agraria	1963	Italy	-	-	-	2230	Soft wheat = 22.3 quintals per hectare

Source	Date	Location	Yield	5 modii per iugerum	6 modii per iugerum	other yield	Notes
Annuario di statistica agraria	1963	Italy	-	-	-	1220	Hard wheat = 12.2 quintals per hectare
van Joolen 2003, p.124	c. 2000	Garfagna - emmer wheat - winter	-	-	-	1000-2000	1-2 tonnes per hectare
van Joolen 2003, p.124	c. 2000	Garfagna - emmer wheat - spring	-	-	-	750-1300	0.75-1.3 tonnes per hectare

***staia** equals 63 **kilograms** of wheat or 1 cubic meter of grain

Table V.2 FAO statistics for grape production 1961-2005

Year	Grapes in kg/ha	Litres per ha Min	Max	Mean
1961	5008	2952	5008	3980
1962	6508	3836	6508	5172
1963	5229	3082	5229	4156
1964	6276.8	3700	6277	4988
1965	6865	4047	6865	5456
1966	6611.1	3897	6611	5254
1967	7884.6	4648	7885	6266
1968	7409.5	4368	7410	5889
1969	8412.8	4959	8413	6686
1970	8058.3	4750	8058	6404
1971	7860.4	4634	7860	6247
1972	7319	4315	7319	5817
1973	9091.7	5360	9092	7226
1974	8946.2	5274	8946	7110
1975	8220.3	4846	8220	6533
1976	7844.4	4624	7844	6234
1977	7506.1	4425	7506	5965
1978	8286.6	4885	8287	6586
1979	10047.7	5923	10048	7985
1980	9818	5788	9818	7803
1981	8169.3	4816	8169	6493
1982	8656.1	5103	8656	6879
1983	11722.3	6910	11722	9316
1984	9775.9	5763	9776	7769
1985	8941.9	5271	8942	7107
1986	10874.7	6411	10875	8643
1987	10897.9	6424	10898	8661
1988	9123	5378	9123	7251
1989	9111.3	5371	9111	7241
1990	8238	4856	8238	6547
1991	9464.9	5580	9465	7522
1992	10892.5	6421	10893	8657
1993	10282.2	6061	10282	8172
1994	10070.3	5936	10070	8003
1995	9395.7	5539	9396	7467
1996	10560	6225	10560	8393
1997	9161.2	5401	9161	7281
1998	10586.6	6241	10587	8414
1999	10672.6	6291	10673	8482
2000	10162.9	5991	10163	8077
2001	10063.4	5932	10063	7998
2002	8840.9	5212	8841	7026
2003	8949.7	5276	8950	7113
2004	10351	6102	10351	8226
2005	11573.4	6823	11573	9198

Appendix VI. BMR tables for stature and weight

Table VI.1 Height ranges based on data from Chapter 7, Table 7.10

	Range for Men	Range for women
Height	163.5-172	152.4-164
Age	15-25-35-45	15-25-35-45

Table VI.2 Daily BMRs at different nutritional levels and different ages

	Height	Weight in kg	Age			
			15	25	35	45
Male Undernourished	163.50	46.78	59.44	56.62	53.81	50.99
	172.00	51.77	64.07	61.25	58.44	55.63
Male Healthy	163.50	66.83	70.93	68.11	65.30	62.48
	172.00	73.96	76.78	73.97	71.15	68.34
Female Undernourished	152.40	40.65	53.61	50.79	47.98	45.16
	164.00	47.07	59.71	56.89	54.08	51.26
Female Healthy	152.40	58.06	63.59	60.77	57.96	55.14
	164.00	67.24	71.26	68.45	65.64	62.82

Table VI.3 Nine hour working day (males)

Short undernourished male	height	163.50	163.50	163.50	163.50
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	46.78	46.78	46.78	46.78
	BMR hourly	59.44	56.62	53.81	50.99
	Light	2252.69	2146.02	2039.35	1932.67
	Moderate	2787.63	2655.63	2523.62	2391.62
	Heavy	3376.07	3216.20	3056.33	2896.46
	Col workload	1113240.25	1060524.51	1007808.77	955093.03
	Total daily	3049.97	2905.55	2761.12	2616.69
Short healthy male	height	163.50	163.50	163.50	163.50
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	66.83	66.83	66.83	66.83
	BMR hourly	70.93	68.11	65.30	62.48
	Light	2688.08	2581.41	2474.74	2368.06
	Moderate	3326.41	3194.41	3062.41	2930.40
	Heavy	4028.58	3868.71	3708.84	3548.97
	Col workload	1328401.94	1275686.20	1222970.46	1170254.72
	Total daily	3639.46	3495.03	3350.60	3206.18
Tall undernourished male	height	172.00	172.00	172.00	172.00
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	51.77	51.77	51.77	51.77
	BMR hourly	64.07	61.25	58.44	55.63
	Light	2428.23	2321.55	2214.88	2108.21
	Moderate	3004.85	2872.85	2740.84	2608.84
	Heavy	3639.14	3479.27	3319.40	3159.53
	Col workload	1199986.14	1147270.40	1094554.66	1041838.92
	Total daily	3287.63	3143.21	2998.78	2854.35
Tall healthy male	height	172.00	172.00	172.00	172.00
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	73.96	73.96	73.96	73.96
	BMR hourly	76.78	73.97	71.15	68.34
	Light	2910.06	2803.39	2696.72	2590.04
	Moderate	3601.11	3469.10	3337.10	3205.10
	Heavy	4361.26	4201.39	4041.52	3881.65
	Col workload	1438100.91	1385385.17	1332669.43	1279953.69
	Total daily	3940.00	3795.58	3651.15	3506.72

Table VI.4 Nine hour working day (females)

Short undernourished female	height	152.40	152.40	152.40	152.40
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	40.65	40.65	40.65	40.65
	BMR hourly	53.61	50.79	47.98	45.16
	Light	2031.73	1925.06	1818.39	1711.72
	Moderate	2514.20	2382.20	2250.20	2118.19
	Heavy	3044.92	2885.05	2725.18	2565.31
	Col workload	1004046.20	951330.46	898614.72	845898.98
	Total daily	2750.81	2606.38	2461.96	2317.53
Short healthy female	height	152.40	152.40	152.40	152.40
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	58.06	58.06	58.06	58.06
	BMR hourly	63.59	60.77	57.96	55.14
	Light	2410.01	2303.34	2196.67	2089.99
	Moderate	2982.31	2850.31	2718.30	2586.30
	Heavy	3611.84	3451.97	3292.10	3132.23
	Col workload	1190984.96	1138269.23	1085553.49	1032837.75
	Total daily	3262.97	3118.55	2974.12	2829.69
Tall undernourished female	height	164.00	164.00	164.00	164.00
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	47.07	47.07	47.07	47.07
	BMR hourly	59.71	56.89	54.08	51.26
	Light	2262.87	2156.19	2049.52	1942.85
	Moderate	2800.22	2668.22	2536.21	2404.21
	Heavy	3391.31	3231.45	3071.58	2911.71
	Col workload	1118267.83	1065552.09	1012836.35	960120.61
	Total daily	3063.75	2919.32	2774.89	2630.47
Tall healthy female	height	164.00	164.00	164.00	164.00
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	67.24	67.24	67.24	67.24
	BMR hourly	71.26	68.45	65.64	62.82
	Light	2700.92	2594.25	2487.58	2380.90
	Moderate	3342.30	3210.30	3078.29	2946.29
	Heavy	4047.82	3887.95	3728.08	3568.22
	Col workload	1334747.50	1282031.77	1229316.03	1176600.29
	Total daily	3656.84	3512.42	3367.99	3223.56

Table VI.5 Three hour working day (males)

Short undernourished male	height	163.50	163.50	163.50	163.50
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	46.78	46.78	46.78	46.78
	BMR hourly	59.44	56.62	53.81	50.99
	Light	2145.70	2044.10	1942.49	1840.89
	Moderate	2324.02	2213.97	2103.92	1993.87
	Heavy	2520.16	2400.82	2281.49	2162.15
	Col workload	880184.64	838504.88	796825.13	755145.37
	Total daily	2411.46	2297.27	2183.08	2068.89
Short healthy male	height	163.50	163.50	163.50	163.50
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	66.83	66.83	66.83	66.83
	BMR hourly	70.93	68.11	65.30	62.48
	Light	2560.42	2458.81	2357.20	2255.60
	Moderate	2773.19	2663.14	2553.09	2443.04
	Heavy	3007.25	2887.91	2768.57	2649.23
	Col workload	1050302.47	1008622.71	966942.96	925263.20
	Total daily	2877.54	2763.35	2649.16	2534.97
Tall undernourished male	height	172.00	172.00	172.00	172.00
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	51.77	51.77	51.77	51.77
	BMR hourly	64.07	61.25	58.44	55.63
	Light	2312.90	2211.30	2109.69	2008.08
	Moderate	2505.11	2395.06	2285.01	2174.96
	Heavy	2716.54	2597.20	2477.86	2358.52
	Col workload	948770.37	907090.62	865410.86	823731.10
	Total daily	2599.37	2485.18	2370.99	2256.80
Tall healthy male	height	172.00	172.00	172.00	172.00
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	73.96	73.96	73.96	73.96
	BMR hourly	76.78	73.97	71.15	68.34
	Light	2771.85	2670.25	2568.64	2467.03
	Moderate	3002.20	2892.15	2782.10	2672.05
	Heavy	3255.58	3136.25	3016.91	2897.57
	Col workload	1137036.08	1095356.32	1053676.57	1011996.81
	Total daily	3115.17	3000.98	2886.79	2772.59

Table VI.6 Three hour working day (females)

Short undernourished female	height	152.40	152.40	152.40	152.40
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	40.65	40.65	40.65	40.65
	BMR hourly	53.61	50.79	47.98	45.16
	Light	1935.24	1833.63	1732.03	1630.42
	Moderate	2096.06	1986.01	1875.96	1765.91
	Heavy	2272.97	2153.63	2034.29	1914.95
	Col workload	793850.24	752170.49	710490.73	668810.97
	Total daily	2174.93	2060.74	1946.55	1832.36
Short healthy female	height	152.40	152.40	152.40	152.40
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	58.06	58.06	58.06	58.06
	BMR hourly	63.59	60.77	57.96	55.14
	Light	2295.55	2193.95	2092.34	1990.73
	Moderate	2486.32	2376.27	2266.22	2156.17
	Heavy	2696.16	2576.82	2457.49	2338.15
	Col workload	941653.59	899973.83	858294.07	816614.31
	Total daily	2579.87	2465.68	2351.49	2237.30
Tall undernourished female	height	164.00	164.00	164.00	164.00
	age	15	25	35	45
	BMI	17.5	17.5	17.5	17.5
	weight kg	47.07	47.07	47.07	47.07
	BMR hourly	59.71	56.89	54.08	51.26
	Light	2155.39	2053.79	1952.18	1850.58
	Moderate	2334.51	2224.46	2114.41	2004.36
	Heavy	2531.54	2412.21	2292.87	2173.53
	Col workload	884159.70	842479.94	800800.19	759120.43
	Total daily	2422.36	2308.16	2193.97	2079.78
Tall healthy female	height	164.00	164.00	164.00	164.00
	age	15	25	35	45
	BMI	25	25	25	25
	weight kg	67.24	67.24	67.24	67.24
	BMR hourly	71.26	68.45	65.64	62.82
	Light	2572.65	2471.04	2369.43	2267.83
	Moderate	2786.44	2676.39	2566.34	2456.29
	Heavy	3021.61	2902.27	2782.94	2663.60
	Col workload	1055319.60	1013639.84	971960.08	930280.33
	Total daily	2891.29	2777.10	2662.90	2548.71

Appendix VII. GIS Metadata

Base Data

File name	Program	Brief description
Sesites	ArcView	Original coverage of all South Etruria sites
Toponyms	ArcView	Place names in the study area
EI_rural	ArcView	Vector point file of Early Imperial rural sites (farms and villas)
EI_farms	ArcView	Vector point file of Early Imperial farm sites
EI_villas	ArcView	Vector point file of Early Imperial villa sites
EI_towns	ArcView	Vector point file of Early Imperial towns
EI_centres	ArcView	Vector point file of Early Imperial urban centres
Dem30	ArcView	30m resolution Digital Elevation Model
Rome_anc	ArcView	Vector polygon. Extent of ancient Rome
Rome_mod	ArcView	Vector polygon. Extent of modern Rome
Tvp_area	ArcView	Vector polygon. Outline of study area
setrurias	ArcView	Outline of extent of all South Etruria surveys
Mills	ArcView	Vector point file of mills and querns in the study area, from SE database
Morley	ArcView	Derived place names from toponyms and coded with production type from Neville Morley and ancient texts
Pollencores	ArcView	Location of pollen cores
Rectify_nepi_catasto	ArcView	Rectified image of Nepi's cadastral map
Nepi_polygon	ArcView	Digitised field boundaries from 'Rectify_nepi_catasto' showing cultivated crop
EI_rural	Idrisi	Vector point file of Early Imperial rural sites (farms and villas)
EI_farms	Idrisi	Vector point file of Early Imperial farm sites
EI_villas	Idrisi	Vector point file of Early Imperial villa sites
EI_towns	Idrisi	Vector point file of Early Imperial towns
EI_centres	Idrisi	Vector point file of Early Imperial urban centres
LR_rural	Idrisi	Vector point file of Late Republican rural sites (farms and villas)
LR_farms	Idrisi	Vector point file of Late Republican farm sites
LR_villas	Idrisi	Vector point file of Late Republican villa sites
LR_towns	Idrisi	Vector point file of Late Republican towns
LR_centres	Idrisi	Vector point file of Late Republican urban centres
Studyarea	Idrisi	Vector polygon file of study area
Etruria	Idrisi	Vector polygon file of Etrurian study area
Sabina	Idrisi	Vector polygon file of Sabine study area
Geology	Idrisi	Vector polygon file of geology
Landuse	Idrisi	Vector polygon file of land use
Soil	Idrisi	Vector polygon file of soil
Rivers	Idrisi	Vector line file of rivers
Roads_Roman	Idrisi	Vector line file of Roman roads
EI_rural	Idrisi	Raster image. Early Imperial rural sites (farms and villas)
EI_farms	Idrisi	Raster image. Early Imperial farm sites
EI_villas	Idrisi	Raster image. Early Imperial villa sites
EI_towns	Idrisi	Raster image. Early Imperial towns
EI_centres	Idrisi	Raster image. Early Imperial urban centres
LR_rural	Idrisi	Raster image. Late Republican rural sites (farms and villas)
LR_farms	Idrisi	Raster image. Late Republican farm sites
LR_villas	Idrisi	Raster image. Late Republican villa sites
LR_towns	Idrisi	Raster image. Late Republican towns
LR_centres	Idrisi	Raster image. Late Republican urban centres
Studyarea	Idrisi	Raster image. Study area
DEM	Idrisi	Raster image. Digital Elevation Model
Geology	Idrisi	Raster image. Geology
Landuse	Idrisi	Raster image. Land use
Soil	Idrisi	Raster image. Soil
Rivers_all	Idrisi	Raster image. All rivers

Roads_all	Idrisi	Raster image. All roads
Slope	Idrisi	Raster image. Percent slope derived from DEM
Aspect	Idrisi	Raster image. Aspect derived from DEM
Altitude100	Idrisi	Raster image. DEM reclassified into 100m categories for altitude
Arable	Idrisi	Raster image. Modern arable cultivation, derived from Land use
Olive	Idrisi	Raster image. Modern olive cultivation, derived from Land use
Complex	Idrisi	Raster image. Modern complex cultivation, derived from Land use
Woodland	Idrisi	Raster image. Modern woodland, derived from Land use
Water	Idrisi	Raster image. Modern water bodies, derived from Land use
Vines	Idrisi	Raster image. Modern vine cultivation, derived from Land use

Territory size

File name	Program	Brief description
Italy	ArcView	Vector polygon. Outline of the country of Italy
Landsize_all	ArcView	Vector point. All points derived from landsize database
No_centuriation	ArcView	'Landsize_all' with centuriated entries removed
Pre30BC	ArcView	'No_centuriation' with only records from pre 30 BC
Imperiallandsize	ArcView	'No_centuriation' with only records from 30 BC – AD 100
Farm_alloc	Idrisi	Raster image. Allocation module run on farm coverage
Rural_alloc	Idrisi	Raster image. Allocation module run on all rural sites
EI-rural_2iug	Idrisi	Raster image. Early Imperial rural sites with 2 *iugera* buffers
EI-rural_5iug	Idrisi	Raster image. Early Imperial rural sites with 5 *iugera* buffers
EI-rural_12iug	Idrisi	Raster image. Early Imperial rural sites with 12 *iugera* buffers
EI-rural_40iug	Idrisi	Raster image. Early Imperial rural sites with 40 *iugera* buffers
EI-rural_100iug	Idrisi	Raster image. Early Imperial rural sites with 100 *iugera* buffers
EI-farms_12iug	Idrisi	Raster image. Early Imperial farms with 12 *iugera* buffers
EI-villas_100iug	Idrisi	Raster image. Early Imperial villas with 100 *iugera* buffers
LR-rural_2iug	Idrisi	Raster image. Late Republican rural sites with 2 *iugera* buffers
LR -rural_5iug	Idrisi	Raster image. Late Republican rural sites with 5 *iugera* buffers
LR-rural_12iug	Idrisi	Raster image. Late Republican rural sites with 12 *iugera* buffers
LR-rural_40iug	Idrisi	Raster image. Late Republican rural sites with 40 *iugera* buffers
LR-rural_100iug	Idrisi	Raster image. Late Republican rural sites with 100 *iugera* buffers
LR-farms_12iug	Idrisi	Raster image. Late Republican farms with 12 *iugera* buffers
LR-villas_100iug	Idrisi	Raster image. Late Republican villas with 100 *iugera* buffers

Locational analysis

File name	Program	Brief description
Aspect360	Idrisi	Raster image. Aspect derived from DEM
Aspect45	Idrisi	Raster image. Aspect reclassified into 45° categories
Slope	Idrisi	Raster image. Percent slope map derived from DEM
Slope03	Idrisi	Raster image. Slope reclassified into 3% categories
Friction	Idrisi	Raster image. Friction image generated with Pandolf equation and 'slope'
Farm_dist	Idrisi	Raster image. Distance module run on farms
Flat	Idrisi	Raster image. Image with value of 0
Flat_cost	Idrisi	Raster image. Cost surface run on 'Flat'
Flat_dist	Idrisi	Raster image. Distance module run on 'Flat'
Flat_frict	Idrisi	Raster image. Friction image generated with Pandolf equation and 'Flat'
EI-centres_dist	Idrisi	Raster image. Distance module run on 'ei-centres'
EI-centres_dist500	Idrisi	Raster image. 'ei-centres_dist' reclassified into 500m categories
EI-centres_cost	Idrisi	Raster image. Cost surface run on 'ei-centres' using 'friction'
EI-centres_cost5k	Idrisi	Raster image. 'EI-centres_cost' reclassified into 5k equivalents
EI-towns_dist	Idrisi	Raster image. Distance module run on 'ei- towns

EI- towns _dist500	Idrisi	Raster image. 'ei- towns _dist' reclassified into 500m categories
EI- towns _cost	Idrisi	Raster image. Cost surface run on 'ei- towns using 'friction'
EI- towns _cost5k	Idrisi	Raster image. 'EI- towns _cost' reclassified into 5k equivalents
Roads_all_dist	Idrisi	Raster image. Distance module run on 'roads-all'
Roads_all_dist100	Idrisi	Raster image. 'roads_all_dist' reclassified into 100m categories
Roads_pav_dist	Idrisi	Raster image. Distance module run on 'roads-pav'
Roads_pav_dist100	Idrisi	Raster image. 'roads_pav_dist' reclassified into 100m categories
Rivers_all_dist	Idrisi	Raster image. Distance module run on 'water-all'
Rivers _all_dist100	Idrisi	Raster image. 'Rivers_all_dist' reclassified into 100m categories
Rivers _maj_dist	Idrisi	Raster image. Distance module run on 'Rivers-maj'
Rivers _maj_dist100	Idrisi	Raster image. 'Rivers_maj_dist' reclassified into 100m categories

MCE arable analysis

File name	Program	Brief description
Mask-all	Idrisi	Raster image. Binary mask of study area and limits of DEM
Lakes_constraint	Idrisi	Raster image. Binary mask of lakes
Dem_wheataltitude1200	Idrisi	Raster image. Binary mask excluding altitude over 1200m asl
Mce1_aspect	Idrisi	Raster image. Factor map (0-255) for aspect, coded for arable
Mce1_lrcentrescost	Idrisi	Raster image. Factor map (0-255) for cost distance to Late Republican centres
Mce1_eicentrescost	Idrisi	Raster image. Factor map (0-255) for cost distance to Early Imperial centres
Mce1_fertility	Idrisi	Raster image. Factor map (0-255) for arable fertility based on geology
Mce1_roadcost	Idrisi	Raster image. Factor map (0-255) for cost distance to roads
Mce1_slope	Idrisi	Raster image. Factor map (0-255) for slope, coded for arable
Mce1_watercost	Idrisi	Raster image. Factor map (0-255) for cost distance to water
Mce1a	Idrisi	Raster image. Multi-Criteria Analysis results for equal weighting Late Republican model
Mce1b	Idrisi	Raster image. Multi-Criteria Analysis results for equal weighting Early Imperial model
Mce2a	Idrisi	Raster image. Multi-Criteria Analysis results for weighted Late Republican model
Mce2b	Idrisi	Raster image. Multi-Criteria Analysis results for weighted Early Imperial model

MCE olive analysis

File name	Program	Brief description
Mce3_olivealtitudelimit	Idrisi	Raster image. Binary mask excluding altitude over 800m
Mce3_aspect	Idrisi	Raster image. Factor map (0-255) for aspect, coded for olives
Mce3_slope	Idrisi	Raster image. Factor map (0-255) for slope, coded for olives
Mce3_fertility	Idrisi	Raster image. Factor map (0-255) for olive fertility based on geology
Mce3a	Idrisi	Raster image. Multi-Criteria Analysis results for equal weighting Late Republican model
Mce3b	Idrisi	Raster image. Multi-Criteria Analysis results for equal weighting Early Imperial model
Mce4a	Idrisi	Raster image. Multi-Criteria Analysis results for weighted Late Republican model
Mce4b	Idrisi	Raster image. Multi-Criteria Analysis results for weighted Early Imperial model

MCE quartiles

File name	Program	Brief description
Mce1b_quart	Idrisi	Mce1b reclassified into quartiles
Mce1b_octiles	Idrisi	Mce1b reclassified into octiles
Mce2b_quart	Idrisi	Mce2b reclassified into quartiles
Mce2b_octiles	Idrisi	Mce2b reclassified into octiles
Mce3b_quart	Idrisi	Mce3b reclassified into quartiles
Mce3b_octiles	Idrisi	Mce3b reclassified into octiles
Mce4b_quart	Idrisi	Mce4b reclassified into quartiles
Mce4b_octiles	Idrisi	Mce4b reclassified into octiles
Mce1b_quart3-4	Idrisi	Mce1b_quart reclassified to show top two quartiles only
Mce2b_quart3-4	Idrisi	Mce2b_quart reclassified to show top two quartiles only
Mce3b_quart3-4	Idrisi	Mce3b_quart reclassified to show top two quartiles only
Mce4b_quart3-4	Idrisi	Mce4b_quart reclassified to show top two quartiles only
Complex comparison_1b3b	Idrisi	Mce1b_quart3-4 + Mce3b_quart3-4 overlaid
Complex comparison_2b4b	Idrisi	Mce2b_quart3-4 + Mce4b_quart3-4 overlaid

Yield maps

File name	Program	Brief description
Yield_arable15-1	Idrisi	Raster image. Arable yield map showing 15:1 yield and 5 *modii* / *iugerum* sowing rate
Yield_arable15-1_10	Idrisi	Raster image. Arable yield map showing 15:1 yield and 10 *modii* / *iugerum* sowing rate
Yield_arable8-1	Idrisi	Raster image. Arable yield map showing 8:1 yield and 5 *modii* / *iugerum* sowing rate
Yield_arable8-1_10	Idrisi	Raster image. Arable yield map showing 8:1 yield and 10 *modii* / *iugerum* sowing rate
Yield_arable4-1	Idrisi	Raster image. Arable yield map showing 4:1 yield and 5 *modii* / *iugerum* sowing rate
Yield_arable4-1_10	Idrisi	Raster image. Arable yield map showing 4:1 yield and 10 *modii* / *iugerum* sowing rate
Intercropping15-1	Idrisi	Raster image. Intercropping yield map. ‘Yield_arable15-1’ / 2
Intercropping15-1_10	Idrisi	Raster image. Intercropping yield map. ‘Yield_arable15-1_10’ / 2
Intercropping8-1	Idrisi	Raster image. Intercropping yield map. ‘Yield_arable8-1’ / 2
Intercropping8-1_10	Idrisi	Raster image. Intercropping yield map. ‘Yield_arable8-1_10’ / 2
Intercropping4-1	Idrisi	Raster image. Intercropping yield map. ‘Yield_arable4-1’ / 2
Intercropping4-1_10	Idrisi	Raster image. Intercropping yield map. ‘Yield_arable4-1_10’ / 2
Yield_olive214	Idrisi	Raster image. Intercropping olive yield, max 214kgs/ha. Mce3b * (214 / 255)

Yield territories

File name	Program	Brief description
15-1_2iug	Idrisi	Raster image. All farm sites with 2 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_5iug	Idrisi	Raster image. All farm sites with 5 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_12iug	Idrisi	Raster image. All farm sites with 12 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_28iug	Idrisi	Raster image. All farm sites with 28 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_40iug	Idrisi	Raster image. All farm sites with 40 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_100iug	Idrisi	Raster image. All villa sites with 100 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_2iug_10	Idrisi	Raster image. All farm sites with 2 iugera buffers overlaid with

		15:1 yield and 10 modii sowing rate.
15-1_5iug_10	Idrisi	Raster image. All farm sites with 5 iugera buffers overlaid with 15:1 yield and 10 modii sowing rate.
15-1_12iug_10	Idrisi	Raster image. All farm sites with 12 iugera buffers overlaid with 15:1 yield and 10 modii sowing rate.
15-1_28iug_10	Idrisi	Raster image. All farm sites with 28 iugera buffers overlaid with 15:1 yield and 10 modii sowing rate.
15-1_40iug_10	Idrisi	Raster image. All farm sites with 40 iugera buffers overlaid with 15:1 yield and 10 modii sowing rate.
15-1_100iug_10	Idrisi	Raster image. All villa sites with 100 iugera buffers overlaid with 15:1 yield and 10 modii sowing rate.
8-1_12iug	Idrisi	Raster image. All farm sites with 12 iugera buffers overlaid with 8:1 yield and 5 modii sowing rate.
8-1_12iug_10	Idrisi	Raster image. All farm sites with 12 iugera buffers overlaid with 8:1 yield and 10 modii sowing rate.
8-1_100iug	Idrisi	Raster image. All villa sites with 100 iugera buffers overlaid with 8:1 yield and 5 modii sowing rate.
8-1_100iug_10	Idrisi	Raster image. All villa sites with 100 iugera buffers overlaid with 8:1 yield and 10 modii sowing rate.
4-1_12iug	Idrisi	Raster image. All farm sites with 12 iugera buffers overlaid with 4:1 yield and 5 modii sowing rate.
4-1_12iug_10	Idrisi	Raster image. All farm sites with 12 iugera buffers overlaid with 4:1 yield and 10 modii sowing rate.
4-1_100iug	Idrisi	Raster image. All villa sites with 100 iugera buffers overlaid with 4:1 yield and 5 modii sowing rate.
4-1_100iug_10	Idrisi	Raster image. All villa sites with 100 iugera buffers overlaid with 4:1 yield and 10 modii sowing rate.
Intercropping15-1	Idrisi	'Yield_arable15-1' / 2 to produce halved wheat yield
Intercropping15-1_10	Idrisi	'Yield_arable15-1_10' / 2 to produce halved wheat yield
Intercropping8-1	Idrisi	'Yield_arable8-1' / 2 to produce halved wheat yield
Intercropping8-1_10	Idrisi	'Yield_arable8-1_10' / 2 to produce halved wheat yield
Intercropping4-1	Idrisi	'Yield_arable4-1' / 2 to produce halved wheat yield
Intercropping4-1_10	Idrisi	'Yield_arable4-1_10' / 2 to produce halved wheat yield
Intercrop_farms15-1	Idrisi	Intercropping15-1 * ei-farms_12iug
Intercrop_farms15-1_10	Idrisi	Intercropping15-1_10 * ei-farms_12iug
Intercrop_farms8-1	Idrisi	Intercropping8-1 * ei-farms_12iug
Intercrop_farms8-1_10	Idrisi	Intercropping8-1_10 * ei-farms_12iug
Intercrop_farms4-1	Idrisi	Intercropping4-1 * ei-farms_12iug
Intercrop_farms4-1_10	Idrisi	Intercropping4-1_10 * ei-farms_12iug
Intercrop_farms15-1	Idrisi	Intercropping15-1 * ei-farms_12iug
Intercrop_villas15-1_10	Idrisi	Intercropping15-1_10 * ei-villas_100iug
Intercrop_villas8-1	Idrisi	Intercropping8-1 * ei-villas_100iug
Intercrop_villas8-1_10	Idrisi	Intercropping8-1_10 * ei-villas_100iug
Intercrop_villas4-1	Idrisi	Intercropping4-1 * ei-villas_100iug
Intercrop_villas4-1_10	Idrisi	Intercropping4-1_10 * ei-villas_100iug

Random sample

File name	Program	Brief description
Buffer_of_EI_farms	ArcView	Shapefile. Farm sites with 12 iugera buffer
Buffer_of_EI_villas	ArcView	Shapefile. Villa sites with 100 iugera buffer
Buffer_union	ArcView	Shapefile. 'Buffer_of_EI_farms' + 'Buffer_of_EI_villas'
Sample_villas1308	ArcView	Shapefile. 1308 sample villas generated using "Random Point Generation" avoiding 'buffer_union'
Buffer_of_sample_villas	ArcView	Shapefile. Sample villa sites with 100 iugera buffers
Union_orig+1308	ArcView	Shapefile. 'buffer_union' + 'Buffer_of_sample_villas'
Sample_farms1070	ArcView	Shapefile. 1070 sample farms generated avoiding 'Union_orig+1308'
Sample_farms1070	Idrisi	Vector point file imported from ArcView
Sample_villas1308	Idrisi	Vector point file imported from ArcView
Sample_farms1070	Idrisi	Raster image. Converted vector to raster

Sample_farms1605	Idrisi	Raster image. ‘Sample_farms1070’ added to existing farm coverage
Sample_villas1308	Idrisi	Raster image. Converted vector to raster
Sample_villas1962	Idrisi	Raster image. ‘Sample_villas1308’ added to existing farm coverage
Sample_farms12iug	Idrisi	Raster image. ‘Sample_farms1605’ with 12 *iugera* buffers
Sample_villas100iug	Idrisi	Raster image. ‘Sample_villas1962’ with 100 *iugera* buffers
15-1_12iug_S	Idrisi	Raster image. All sample farm sites with 12 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_12iug_10_S	Idrisi	Raster image. All sample farm sites with 12 iugera buffers overlaid with 15:1 yield and 10 modii sowing rate.
15-1_100iug_S	Idrisi	Raster image. All sample villa sites with 100 iugera buffers overlaid with 15:1 yield and 5 modii sowing rate.
15-1_100iug_10_S	Idrisi	Raster image. All sample villa sites with 100 iugera buffers overlaid with:1 yield and 10 modii sowing rate.
8-1_12iug_S	Idrisi	Raster image. All sample farm sites with 12 iugera buffers overlaid with 8:1 yield and 5 modii sowing rate.
8-1_12iug_10_S	Idrisi	Raster image. All sample farm sites with 12 iugera buffers overlaid with 8:1 yield and 10 modii sowing rate.
8-1_100iug_S	Idrisi	Raster image. All sample villa sites with 100 iugera buffers overlaid with 8:1 yield and 5 modii sowing rate.
8-1_100iug_10_S	Idrisi	Raster image. All sample villa sites with 100 iugera buffers overlaid with 8:1 yield and 10 modii sowing rate.
4-1_12iug_S	Idrisi	Raster image. All sample farm sites with 12 iugera buffers overlaid with 4:1 yield and 5 modii sowing rate.
4-1_12iug_10_S	Idrisi	Raster image. All sample farm sites with 12 iugera buffers overlaid with 4:1 yield and 10 modii sowing rate.
4-1_100iug_S	Idrisi	Raster image. All sample villa sites with 100 iugera buffers overlaid with 4:1 yield and 5 modii sowing rate.
4-1_100iug_10_S	Idrisi	Raster image. All sample villa sites with 100 iugera buffers overlaid with 4:1 yield and 10 modii sowing rate.
Intercrop_farms15-1_S	Idrisi	Intercropping15-1 * sample_farms_12iug
Intercrop_farms15-1_10_S	Idrisi	Intercropping15-1_10 * sample_farms_12iug
Intercrop_farms8-1_S	Idrisi	Intercropping8-1 * sample_farms_12iug
Intercrop_farms8-1_10_S	Idrisi	Intercropping8-1_10 * sample_farms_12iug
Intercrop_farms4-1_S	Idrisi	Intercropping4-1 * sample_farms_12iug
Intercrop_farms4-1_10_S	Idrisi	Intercropping4-1_10 * sample_farms_12iug
Intercrop_farms15-1_S	Idrisi	Intercropping15-1 * sample_farms_12iug
Intercrop_villas15-1_10_S	Idrisi	Intercropping15-1_10 * sample_villas_100iug
Intercrop_villas8-1_S	Idrisi	Intercropping8-1 * sample_villas_100iug
Intercrop_villas8-1_10_S	Idrisi	Intercropping8-1_10 * sample_villas_100iug
Intercrop_villas4-1_S	Idrisi	Intercropping4-1 * sample_villas_100iug
Intercrop_villas4-1_10_S	Idrisi	Intercropping4-1_10 * sample_-villas_100iug

BIBLIOGRAPHY

Primary Sources

Apicius *De Re Coquinaria* (transl. J.D. Vehling 1936) Dover Publications (repr. 1977)

Appian (*B Civ*) *The Civil Wars* (transl. H. White 1979) Loeb Classical Library

Caesar (*B Civ) The Civil Wars* (transl. A.G.Peskett 1914) Loeb Classical Library

Cassius Dio *Roman History* (transl. E. Cary and H.B. Foster 1916) Loeb Classical Library

Cassiodorus (*Var.*) *Variae Epistolae* (transl. S.J.B. Barnish 1992) Liverpool University Press

Cato (de Agr.) *On Agriculture* (transl. H.B. Ash 1936) Loeb Classical Library

Catullus (transl. F.W. Cornish, J.P. Postgate, J.W. Mackail and G.P. Goold 1913) Loeb Classical Library

Cicero (*Att.*) *Letters to Atticus* (transl. D.R.Shackleton Bailey 1999) Loeb Classical Library

Cicero (*Fam.*) *On Friendship* (transl. W.A. Falconer 1923) Loeb Classical Library

Cicero (*Leg. Agr.*) *Three Speeches on the Agrarian Law Against Rullus* (transl. J.H. Freese 1930) Loeb Classical Library

Cicero (*pro Rosc. Amer.*) Pro Roscio Amerino (transl. J.H. Freese 1930) Loeb Classical Library

Cicero (*Rep.*) *On the Republic* (transl. C.W. Keyes 1928) Loeb Classical Library

Cicero (*Verr.*) Against Verres (transl. L.H.G. Greenwood 1928) Loeb Classical Library

Columella (*Rust.*) On Agriculture (transl. H.B. Ash 1941) Loeb Classical Library

Dionysius of Halicarnassus (*Rom. Ant.*) Roman Antiquities (transl. E. Cary 1937) Loeb Classical Library

Horace (*Epod.*) *Odes and Epodes* (transl. N. Rudd 2004) Loeb Classical Library

Horace (*Odes*) *Odes and Epodes* (transl. N. Rudd 2004) Loeb Classical Library

Horace (*Sat.*) *Satires* (transl. H.R. Fairclough 1926) Loeb Classical Library

Livy *History of Rome* (transl. B.O. Foster 1919) Loeb Classical Library

Martial *Epigrams* (transl. D.R. Shackleton Bailey 1993) Loeb Classical Library

Ovid *Amores* (transl. G. Showerman 1914) Loeb Classical Library

Pliny the Elder (*NH*) *Natural History* (transl. H. Rackham 1950) Loeb Classical Library

Pliny the Younger (*Ep.*) *Letters* (transl. B. Radice 1969) Loeb Classical Library

Plutarch (*Cato Maior*) *Life of Cato the Elder* (transl. B. Perrin 1914) Loeb Classical Library

Plutarch (*Ti. Gracch.*) *Life of Tiberius Gracchus* (transl. B. Perrin 1921) Loeb Classical Library

Polybius *Histories* (transl. W.R. Paton 1922) Loeb Classical Library

Propertius *Elegies* (transl. G.P. Goold 1990) Loeb Classical Library

Sallust *Historiae* (transl. J.C. Rolfe 1921) Loeb Classical Library

Seneca *Epistulae* (transl. R.M. Gummere 1917) Loeb Classical Library

Siculus Flaccus (*De Conc. Agr.*) *The Writings of the Roman Land Surveyors: Introduction, text, translation and commentary* (transl. B. Campbell 2000). The Society for the Promotion of Roman Studies

Statius (*Silv.*) *Silvae* (transl. D.R. Shackleton Bailey 2003) Loeb Classical Library

Strabo *Geography* (transl. H.R. Jones 1917) Loeb Classical Library

Suetonius *Domitian* (transl. J.C. Rolfe 1914) Loeb Classical Library

Suetonius *Nero* (transl. J.C. Rolfe 1914) Loeb Classical Library

Varro (*Rust.*) *On Agriculture* (transl. H.B. Ash 1936) Loeb Classical Library

Vindolanda Tablets Online. Oxford University, http://vindolanda.csad.ox.ac.uk/

Virgil *Georgics* (transl. H.R. Fairclough 1916) Loeb Classical Library

Virgil *Eclogues* (transl. H.R. Fairclough 1916) Loeb Classical Library

Virgil (*Moretum*) *Appendix Vergiliana* (transl. H. Rushton Fairclough 1918) Loeb Classical Library

Secondary Sources

Alcock, S.A. and J.F. Cherry, Eds. (2004). *Side-by-Side Survey. Comparative Regional Studies in the Mediterranean World.* Oxford, Oxbow Books.

Ampolo, C. (1980). "Le condizione materiali della produzione. Agricoltura e paesaggio agrario." Seminario: La formazione della città nel Lazio. Roma, 24-26 giugno 1977. *Dialoghi di Archeologia* **n.s. 2**: 15-46.

Arcaleni, E. (2006). "Secular trend and regional differences in the stature of Italians, 1854–1980." *Economics & Human Biology* **4**(1): 24-38.

Archivio di Stato di Roma (2002). *Progetto IMAGO II* http://www.asrm.archivi.beniculturali.it/index.html (accessed July 2002)

Ashby, T. (1927). *The Roman Campagna in classical times*. London, E. Benn, Ltd.

Astin, A.E. (1978). *Cato the Censor*. Oxford, Oxford University Press.

Attolini, I., F. Cambi, M. Castagna, M. Celuzza, E. Fentress, P. Perkins and E. Regoli (1991). "Political geography and productive geography between the valleys of the Albegna and the Fiora in Northern Etruria". In G. Barker and J. Lloyd (Eds.). *Roman Landscapes*. London, British School at Rome.

Autostrade (1968). "Villa romana di 'Lucus Feroniae' scoperta durante i lavori per la costruzione dell'Autostrade del Sole." *Autostrade* **10**(8): 1-62.

Aykroyd, W.K. and J. Doughty (1970). *Wheat in Human Nutrition*. Rome, FAO.

Banfield, E.C. (1958). *The Moral Basis of a Backward Society*. Glencoe, Illinois, Free Press. Research Center in Economic Development and Cultural Change, University of Chicago.

Barker, G. (1976). "Animal Husbandry at Narce". In T.W. Potter (Ed.). *A Faliscan town in South Etruria. Excavations at Narce 1966-71*. London, The British School at Rome**:** 295-307.

--- (1985). *Prehistoric Farming in Europe*. Cambridge, Cambridge University Press.

--- (1988). "Archaeology and the Etruscan countryside." *Antiquity* **62**(237): 772-785.

--- (1989). "The Archaeology of the Italian Shepherd." *Proceedings of the Cambridge Philological Society* **215**: 1-19.

--- (1995a). *A Mediterranean Valley. Landscape Archaeology and Annales History in the Biferno Valley*. London, Leicester University Press.

---, Ed. (1995b). *The Biferno Valley Survey. The archaeological and geomorphological record*. London, Leicester University Press.

Barker, G. and T. Rasmussen (1998). *The Etruscans*. Oxford, Blackwell Publishing.

Barnish, S.J.B. (1987). "Pigs, Plebeians and Potentes: Rome's Economic Hinterland, c.350-600 A.D." *Papers of the British School at Rome* **55**: 157-185.

Bartolini, G., G. Prevost, C. Messeri, G. Carignani, S. Diulgheroff and A.J. Martinez (2005). *Olive Germplasm. Cultivars and world-wide collections*, FAO Seed and Plant Genetic Resources Service http://apps3.fao.org/wiews/olive/oliv.jsp (accessed December 2006)

Bell, R.M. (1979). *Fate and Honor, Family and Village: Demographic and Cultural Change in Rural Italy since 1800*. Chicago, University of Chicago Press.

Beloch, K.J. (1886). *Die Bevolkerung der griechisch-romischen Welt*. Leipzig, Duncker & Humblot.

--- (1898). "Le Città dell'Italia antica." *Atene e Roma* **1**.

Bergmann, B. (1995). "Vizualizing Pliny's Villas." *Journal of Roman Archaeology* **8**: 406-420.

Berqvist, S. (1992). "Consideration on yields, the distribution of crops and the size of estates: Three Roman agricultural units." *Classica et Mediaevalia* **43**: 111-139.

Billiard, R. (1928). *L'agriculture dans l'antiquité d'après les Géorgiques de Virgile*. Paris, E. de Boccard.

Bintliff, J. (2002). "Settlement Pattern Analysis and Demographic Modeling". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 28-35.

Bintliff, J. and A. Snodgrass (1985). "The Cambridge/Bradford Boeotia Expedition: the first four years." *Journal of Field Archaeology* **12**: 123-161.

Bisel, S. (1988). "The skeletons of Herculaneum, Italy". In B.A. Purdy (Ed.). *Wet Site Archaeology*. Caldwell, NJ, Telford Press**:** 207-218.

Blumer, W. (1964). "The oldest known plan of an inhabited site dating from the Bronze Age, about the middle of the 2nd millenium BC. Rock-drawings in the Val Camonica." *Imago Mundi* **18**: 9-11.

Boardman, J. (1976). "The Olive in the Mediterranean: Its Culture and Use." *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* **275**(936): 187-196.

Boatfield, G. (1980). *Farm Livestock*. Ipswich, Farming Press Ltd.

Bonamici, M. (2000). "Economic Structure". In M. Torelli (Ed.). *The Etruscans*. Milan, Bompiani**:** 73-88.

Bonatti, E. (1963). "Stratigrafia pollinica dei sedimenti post-glaciale di Baccano, lago craterico del Lazio." *Atti della Societa' Toscana di Scienze naturali* **40**: 40-48.

--- (1970). "Pollen Sequence in the Lake Sediments". In G.E. Hutchinson (Ed.). *Ianula: An Account of the History and Development of the Lago di Monterosi, Latium, Italy*. **60:** 26-31.

Bork, H.-R. and A. Lang (2003). "Quantification of past soil erosion and land use. Land cover changes in Germany". In A. Lang, K. Hennrich and R. Dikau (Eds.). *Long Term Hillslope and Fluvial System Modelling. Concepts and Case Studies from the Rhine River Catchment*. Berlin, Springer-Verlag. **101:** 231-239.

Bose, S. (1986). *Agrarian Bengal: Economy, Social Structure and Politics, 1919-1947*. Cambridge, Cambridge University Press.

Bourne, F.C. (1960). "The Roman alimentary program and Italian agriculture." *Transactions and Proceedings of the American Philological Association* **91**: 47-75.

Bowman, A. and D. Thomas (1994). *The Vindolanda Writing Tablets (Tabulae Vindolandenses II)*. London, British Museum Press.

Brögger, J. (1971). *Montevarese. A Study of Peasant Society and Culture in Southern Italy*. Bergen, Universitetsforlaget.

Brothwell, D.R. (1988). "Foodstuffs, Cooking and Drugs". In M. Grant and R. Kitzinger (Eds.). *Civilization of the Ancient Mediterranean*. New York, Scribner's**:** 250-261.

Broughton, A.L. (1936). "The Menologia Rustica." *Classical Philology* **31**(4): 353-356.

Brown, A.G. and C. Ellis (1995). "People, climate and alluviation: theory, research design and new sedimentological and stratigraphic data from Etruria." *Papers of the British School at Rome* **63**: 45-73.

Brunt, P.A. (1962). "The Army and the Land in the Roman Revolution." *Journal of Roman Studies* **52**: 69-86.

--- (1971a). *Italian Manpower* 225 BC - AD 14. Oxford, Clarendon Press.

--- (1971b). *Social Conflicts in the Roman Republic*. London, Chatto and Windus.

--- (1972). "Review of K.D. White, Roman Farming. London: Thames and Hudson, 1970." *Journal of Roman Studies* **62**: 153-158.

--- (1975). "Two Great Roman Landowners." *Latomus* **34**(2): 619-635.

Buckland-Wright, J.C. (1987). "The Animal Bones". In C. Sparey-Green (Ed.). *Excavations at Poundbury Volume 1. The Settlements*. Dorset, The Friary Press Ltd.

Cabaniss, B. (2001). *Preliminary Faunal Report Kiln Deposit, Pizzica-Pantanello, 1981*, The Institute of Classical Archaeology, The University of Texas at Austin http://www.utexas.edu/research/ica/metaponto/meta81/#bio (accessed 10th January 2003)

Cambi, F. (1999). "Demography and Romanization in Central Italy". In J. Bintliff and K. Sbonias (Eds.). *The Archaeology of Mediterranean Landscapes 1: Reconstructing Past Population Trends in Mediterranean Europe (3000 BC - AD 1800)*. Oxford, Oxbow Books.

Campbell, B. (2000). *The Writings of the Roman Land Surveyors: Introduction, text, translation and commentary*, The Society for the Promotion of Roman Studies.

Campbell, J.A. (1978). "Other Diets Relative to Standards of Need". In J. Yudkin (Ed.). *Diet of Man: Needs and Wants*. London, Applied Science Publishers Ltd**:** 47-67.

Carandini, A. (1983). "Columella's Vineyard and the Rationality of the Roman Economy." *Opus* **2**: 177-204.

---, Ed. (1985). *Settefinestre: una villa schiavistica nell' Etruria romana*. Modena, Panini.

Carandini, A. and T. Tatton-Brown (1980). "Excavations at the Roman villa of "Sette Finestre" in Etruria, 1975-9. First Interim Report". In K. Painter (Ed.) *Roman Villas in Italy. Recent excavations and research*. London, British Museum**:** 9-43.

Carter, J. (2001a). *Rural Archaeology at Metaponto: Aims and Results in 1981 and 1982. A Synopsis*, The Institute of Classical Archaeology, The University of Texas at Austin http://www.utexas.edu/research/ica/metaponto/meta81/#rur (accessed 10th January 2003)

--- (2001b). *Excavation, Pizzica-Pantanello The Deposit of Pottery and Bone, 1980-81*, The Institute of Classical Archaeology, The University of Texas at Austin http://www.utexas.edu/research/ica/metaponto/meta81/#bio (accessed 10th January 2003)

Carter, J.C., L. Costantini, C. D'Annibale, J.R. Jones, R.L. Folk, D. Sullivan and M.E. Reed (1985). "Population and Agriculture: Magna Grecia in the fourth century BC". In C.Malone and S. Stoddart (Eds.). *Papers in Italian Archaeology IV. The Cambridge Conference. Part i - The Human Landscape*. 281-312.

Cartwright, C. (1997). "Fish Bones". In T.W. Potter and A.C. King (Eds.). *Excavations at the Mola di Monte Gelato. A Roman and Medieval Settlement in South Etruria*. London, The British School at Rome**:** 404-407.

Cattedra di preistoria e protostoria and Universita' degli studi di Milano (2001). *Aratro* http://users.unimi.it/prehist/itversion/scavi/lavagnone/materiali/aratro.html (accessed January 2007)

Cavalieri Manasse, G. (2000). "Un documento catastale dell'agro centuriato veronese." *Athenaeum* **88**: 5-52.

Champlin, E. (1981). "Owners and Neighbours at Ligures Baebiani." *Chiron* **11**: 239-264.

Cherry, J.F. (1983). "Frogs Round the Pond: Perspectives on Current Archaeological Survey Projects in the Mediterranean Region". In D. Keller and D. Rupp (Eds.). *Archaeological Survey in the Mediterranean Area*. Oxford, British Archaeological Reports**:** 375-415.

Chisholm, M. (1973). *Rural Settlement and Land Use*. London, Hutchinson University Library.

Christaller, W. (1966). *Central Places in Southern Germany*. Englewood Cliffs, N.J., Prentice-Hall.

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

Coarelli, F. and P.G. Monti (1998). *Fregellae 1. Le fonti, la storia, il territorio*. Perugia, Quasar / Università degli Studi.

Coccia, S. and D.J. Mattingly (1992). "Settlement history, environment and human exploitation of an intermontane basin in the Central Appenines: the Rieti Survey 1988-1991." *Papers of the British School at Rome* **60**: 213-289.

Consorzio provinciale per l'Olivicoltura di Rieti (1938). *Olivicoltura Sabina* 1. Rieti.

Costantini, L. (2001). *Bioarchaelogical Research at Pizzica-Pantanello*, The Institute of Classical Archaeology, The University of Texas at Austin http://www.utexas.edu/research/ica/metaponto/meta81/#bio (accessed 10th January 2003)

Cresswell, R. (1965). "Un pressoir à olives au Liban: essai de technologie comparée." *L'Homme. Cahiers d'Ethnologie* **5.1**: 33-66.

Cucina, A., R. Vargiu, D. Mancinelli, R. Ricci, E. Santandrea, P. Catalano and A. Coppa (2006). "The Necropolis of Vallerano (Rome, 2nd-3rd Century AD): An Anthropological Perspective on the Ancient Romans in the Suburbium." *International Journal of Osteoarchaeology* **16**: 104-117.

Davis, J. (1973). *Land and Family in Pisticci*. London, Athlone Press.

Davis, S.J.M. (1987). *The Archaeology of Animals*. London, B.T. Batsford.

Day, J. (1932). "Agriculture in the life of Pompeii." *Yale Classical Studies* **3**: 167-208.

De Angelis, F. (2000). "Estimating the Agricultural base of Greek Sicily." *Papers of the British School at Rome* **68**: 111-148.

De Grossi Mazzorin, J. (1987). "La Fauna". In G. Ghini (Ed.). *La Villa dei Quintili a Monteporizio*. Roma, Consiglio nazionale delle ricerche: Istituto per l'archeologia etrusco-italica**:** 234-235.

--- (2004). "Some considerations about the evolution of the animal exploitation in Central italy from the Bronze Age to the Classical period". In B. Santillo Frizell (Ed.). *PECUS. Man and Animal in Antiquity. Proceedings of the Conference at the Swedish Institute in Rome. September 9-12 2002*. Rome, The Swedish Institute in Rome. Projects and Seminars.

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.

--- (1993). *Fairs and Markets in the Roman Empire. Economic and Social Aspects of Periodic Trade in a Pre-Industrial Society*. Amsterdam, J.C. Gieben.

De Neeve, P.W. (1984). *Peasants in peril. Location and economy in Italy in the second century BC*. Amsterdam, J.C. Gieben.

De Pachtere, F.G. (1920). *La table hypothécaire de Veleia: étude sur la propriété foncière dans l'Apennin de Plaisance*. Paris, É. Champion.

de Tournon, P.C.C.M. (1855). *Études statisiques sur Rome et la partie occidentale des états romains*. Paris.

Delano Smith, C. (1979). *Western Mediterranean Europe. A Historical Geography of Italy, Spain and Southern France since the Neolithic*. London, Academic Press.

Dennis, G. (1848). *The Cities and Cemeteries of Etruria*. London, J. Murray.

Dewey, T. and J. Hruby (2002). *Sus scrofa*, Animal Diversity Web. http://animaldiversity.ummz.umich.edu/site/accounts/information/Sus_scrofa.html (accessed March 2007)

Di Giuseppe, H., M. Sansoni, J. Williams and R. Witcher (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. (1967). "Illustrations from Roman surveyors' manuals." *Imago Mundi* **21**: 9-30.

--- (1992). *The Roman Land Surveyors: An Introduction to the Agrimensores*. Amsterdam, Adolf M. Hakkert.

--- (1998). *Greek and Roman Maps*. Baltimore and London, The Johns Hopkins University Press.

Dohr, H. (1965). *Die italischen Gutshöfe nach den Schriften Catos und Varros*. Köln Dissertation.

Driessen, P. and J. Deckers (2001). *Lecture Notes on the Major Soils of the World*. Rome, FAO.

Dumont, R. (1957). *Types of rural economy. Studies in world agriculture*. London, Methuen.

Duncan, G.C. (1958). "Sutri (Sutrium)." *Papers of the British School at Rome* **26**: 63-134.

Duncan-Jones, R.P. (1962). "Costs, outlays and summae honorariae from Roman Africa." *Papers of the British School at Rome* **30**(n.s. 17): 47-115.

--- (1964). "The Purpose and Organisation of the Alimenta." *Papers of the British School at Rome* **32**: 123-46.

--- (1976). "Some Configurations of Landholding in the Roman Empire". In M.I. Finley (Ed.). *Studies in Roman Property*. Cambridge, Cambridge University Press**:** 7-33.

--- (1982). *The Economy of the Roman Empire: Quantitative Studies*. Cambridge, Cambridge University Press.

Dyson, S. (1978). "Settlement Patterns in the Ager Cosanus: The Wesleyan University Survey, 1974-1976." *Journal of Field Archaeology* **5**(3): 251-268.

--- (1981). "Settlement Reconstruction in the Ager Cosanus and the Albegna Valley: Wesleyan University Research, 1974-1979". In G. Barker and R. Hodges (Eds.). *Archaeology and Italian Society. Prehistoric, Roman and Medieval Studies*. Papers in Italian Archaeology II. 269-274.

--- (1985). "The Villas of Buccino and the Consumer Model of Roman Rural Development". In C.M.a.S. Stoddart (Ed.). *Papers in Italian Archaeology IV. The Cambridge Conference. Part iv - Classical and Medieval Archaeology*.

--- (1992). *Community and Society in Roman Italy*. London, The Johns Hopkins University Press.

Eastman, J.R. (2001). *Guide to GIS and Image Processing Volume 2*. Worcester, MA, Clark Labs.

Ellis, S. and A. Mellor (1995). *Soils and Environment*. London, Routledge.

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

FAO (1973a). *Energy and Protein Requirements*. Geneva, Food and Agriculture Organization of the United Nations.

--- (1973b). "Food and Nutrition: A new view of an old problem." *Nutrition Newsletter* **11**(4): 1.

--- (1976). *A Framework for Land Evaluation*. Rome, Food and Agriculture Organization of the United Nations.

--- (1985). *Energy and Protein Requirements*. Geneva, Food and Agriculture Organization of the United Nations.

--- (2001). *Food Balance Sheets. A handbook*. Rome, Food and Agriculture Organization of the United Nations.

FAOSTAT (2003). *FAO Statistical Databases*, Food and Agriculture Organization of the United Nations http://apps.fao.org/ (accessed 1st September 2003)

FAOSTAT data (2006a). *FAO Statistical Databases. Agricultural Production: Olives*, Food and Agriculture Organization of the United Nations http://faostat.fao.org/ (accessed March 2006)

--- (2006b). *FAO Statistical Databases. Agricultural Production: Grapes*, Food and Agriculture Organization of the United Nations http://faostat.fao.org/ (accessed April 2006)

--- (2006c). *FAO Statistical Databases. Agricultural Production: Livestock Primary*, Food and Agriculture Organization of the United Nations http://faostat.fao.org/ (accessed April 2006)

Farshad, A. (1997). *Analysis of integrated soil and water management practices within different agricultural systems under semi-arid conditions of Iran an evaluation of their sustainability*.

--- (2002). "Land Evaluation in Archaeology, a way to enrich the reconstruction of past agrarian landscape; a case study of Iran". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 189-195.

Favory, F., J.-J. Girardot and M.-P. Zannier (1995). "La perception des sols et des plantes chez les agronomes romains". In S.E. Van der Leeuw (Ed.). *The Archaeomedes Project: Understanding the natural and anthropogenic causes of soil degradation and desertification in the Mediterranean Basin. Volume 3: Dégradation et impact humain dans la moyenne et basse vallée du Rhône dans l'Antiquité (part II)*. Cambridge, Cambridge University Press.

Finke, P., J. Harding, J. Sevink, R. Sewuster and S. Stoddart (1994). "The dissection of a Bronze and early Iron Age landscape". In C. Malone and S. Stoddart (Eds.). *Territory, Time and State. The archaeological development of the Gubbio Basin*. Cambridge, Cambridge University Press**:** 81-93.

Finley, M.I. (1973). *The Ancient Economy.* London, Chatto and Windus.

--- (1977). "The Ancient City: From Fustel de Coulanges to Max Weber and beyond." *Comparative Studies in Society and History* **19**(3): 305-327.

Fletcher, M. and G. Lock (1991). *Digging Numbers. Elementary Statistics for Archaeologists*. Oxford, Oxford University Committee for Archaeology.

Forbes, H. (1982). *Strategies and Soils: Technology, production and environment in the peninsula of Methana, Greece*. Unpublished PhD thesis. University of Pennsylvania.

--- (1989). "Of grandfathers and grand theories: the hierarchised ordering of responses to hazard in a Greek rural community". In P. Halstead and J. O'Shea (Eds.). *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge, Cambridge University Press**:** 87-97.

Forbes, H. and L. Foxhall (1978). "The Queen of all Trees. Preliminary notes on the archaeology of the olive." *Expedition* **21**(1)

--- (1995). "Ethnoarchaeology and Storage in the Ancient Mediterranean". In J. Wilkins, D. Harvey and M. Dobson (Eds.). *Food in Antiquity*. Exeter, University of Exeter Press**:** 69-86.

Forni, G. (1990). *Gli albori dell'agricoltura*. Roma, Reda.

--- (2002). "Palaeo-soils and Prehistoric Agriculture in Central and Southern Italy". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 196-199.

Forsythe, G. (2005). *A Critical History of Early Rome: From Prehistory to the First Punic War*. London, University of California Press.

Foxhall, L. (1996). "Feeling the earth move: cultivation techniques on steep slopes in classical antiquity". In G. Shipley and J. Salmon (Eds.). *Human Landscapes in Classical Antiquity. Environment and Culture*. London, New York, Routledge**:** 44-67.

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

Frank, A.H.E. (1969). "Pollen Stratigraphy of the Lake of Vico (Central Italy)." *Palaeogeography, Palaeoclimatology, Palaeoecology* **6**: 67-85.

Frank, T. (1924). "Roman Census Statistics from 225 to 28 BC." *Classical Philology* **19**(4): 329-341.

--- (1933). *An Economic Survey of Ancient Rome. Volume 1: Rome and Italy of the Republic*. Baltimore, The John Hopkins Press.

--- (1954). "Italy". In S.A. Cook, F.E. Adcock and M.P. Charlesworth (Eds.). *The Cambridge Ancient History. Volume VIII: Rome and the Mediterranean 218-133 B.C.* Cambridge, Cambridge University Press**.**

Frayn, J.M. (1975). "Wild and cultivated plants: a note on the peasant economy of Roman Italy." *Journal of Roman Studies* **65**: 32-38.

--- (1979). *Subsistence Farming in Roman Italy*. Fontwell, Sussex, Centaur Press Ltd.

Frederiksen, M.W. and J.B. Ward Perkins (1957). "The Ancient Road Systems of Central and Northern Ager Faliscus. (Notes on Southern Etruria, 2)." *Papers of the British School At Rome* **25**: 67-205.

Frier, B.W. (1992). "Review of Tim Parkin, Demography and Roman Society." *Bryn Mawr Classical Review* **03.05.13**

--- (2001). "More is worse: Some observations on the population of the Roman Empire". In W. Scheidel (Ed.). *Debating Roman Demography*. Leiden, Brill**:** 139-159.

Fumagalli, V. (1978). *Coloni e signori nell'Italia settemtrionale, secoli VI-XI*. Bologna, Pàtron.

Fussell, G.E. (1967). "Farming Systems of the Classical Era." *Technology and Culture* **8**(1): 16-44.

Gaffney, V., H. Patterson, S. Piro, D. Goodman and Y. Nishimura (2004). "Multimethodological Approach to Study and Characterize Forum Novum (Vescovio, Central Italy)." *Archaeological Prospection* **11**(4): 201-212.

Gaffney, V., H. Patterson and P. Roberts (2001). "Forum Novum-Vescovio: studying urbanism in the Tiber valley." *Journal of Roman Archaeology* **14**(1): 59-79.

Gallant, T. (1991). *Risk and Survival in Ancient Greece. Reconstruction the Rural Domestic Economy*. Cambridge, Polity Press.

Gargola, D.J. (1995). *Lands, Laws and Gods. Magistrates and Ceremony in the Regulation of Public Lands in Republican Rome*. London, University of North Carolina Press.

Garnsey, P. (1988). *Famine and Food Supply in the Graeco-Roman World*. Cambridge, Cambridge University Press.

--- (1998). *Cities, Peasants and Food in Classical Antiquity. Essays in social and economic history*. Cambridge, Cambridge University Press.

--- (1999). *Food and Society in Classical Antiquity*. Cambridge, Cambridge University Press.

Garnsey, P. and R. Saller (1987). *The Roman Empire. Economy, Society and Culture*. London, Duckworth.

Garnsey, P. and C.R. Whittaker, Eds. (1983). *Trade and famine in classical antiquity. Cambridge Philological Society Supplementary Volume 8*. Cambridge, Cambridge Philological Society.

Gell, W. (1834). *The Topography of Rome and its Vicinity*. London, Saunders and Otley.

Gerrard, J. (2000). *Fundamentals of Soils*. London, Routledge.

Giorgi, J. (1997). "The Charred Plant Remains". In T.W. Potter and A.C. King (Eds.). *Excavations at the Mola di Monte Gelato. A Roman and Medieval Settlement in South Etruria*. London, The British School at Rome**:** 407-411.

Grant, M. (1995). *Greek and Roman Historians. Information and Misinformation*. London, Routledge.

Gummerus, H. (1906). *Der römische Gutsbetrieb als wirtschaftlicher Organismus nach den Werken des Cato, varro und Columella*. Leipzig, Dieterich.

Guzzo, P.G. (1970). "Sacrofano - ponte romana in località Fontana Nuova." *Notizie degli Scavi di Antichità* **1970**: 330-344.

Haenlein, G.F.W. (2005). *The Nutritional Value of Sheep Milk*, The British Sheep Dairying Association http://www.sheepdairying.com/haenlein.htm / http://www.smallstock.info/issues/sheepmilk.htm (accessed April 2006)

Hall, A.D. (1905). *The book of the Rothamsted experiments*. London, Murray.

Halstead, J. (1989). "The economy has a normal surplus: economic stability and social change among early farming communities of Thessaly, Greece". In P. Halstead and J. O'Shea (Eds.). *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge, Cambridge University Press**:** 68-80.

Halstead, P. and J. O'Shea (1989). "Introduction: cultural responses to risk and uncertainty". In P. Halstead and J. O'Shea (Eds.). *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge, Cambridge University Press**:** 1-7.

Harris, J.A. and F.G. Benedict (1919). *A biometric study of basal metabolism in man*. Washington, Carnegie Institution of Washington.

Hayes, J. (1972). *Late Roman pottery.* London, British School at Rome.

Hayes, P. (1985). "The San Vincenzo Survey, Molise". In S. Macready and F.H. Thompson (Eds.). *Archaeological Field Survey in Britain and Abroad*. London, Thames & Hudson**:** 129-135.

Haynes, S. (2000). *Etruscan Civilization. A Cultural History*. London, British Museum Press.

Hemphill, P. (1975). "The Cassia-Clodia survey." *Papers of the British School at Rome* **43**: 118-172.

Higginbotham, J. (1997). *Piscinae. Artificial fishponds in Roman Italy*. Chapel Hill and London, The University of North Carolina Press.

Hodge, A.T. (1992). *Roman Aqueducts and Water Supply*. London, Duckworth.

Hodges, R. (1988). "The San Vincenzo Project: preliminary review of the excavations and surveys at San Vincenzo al Volturno and its terra". In N. Noyé (Ed.). *Castrum 2. Structures de l'Habitat et Occupation du Sol dans les Pays Mediterraneens: les méthodes et l'apport de l'archéologie extensive*. Roma, Ecole Française**:** 421-431.

Hopkins, K. (1978). *Conquerors and Slaves. Sociological studies in Roman history Volume 1*. Cambridge, Cambridge University Pres.

--- (1980). "Taxes and Trade in the Roman Empire." *Journal of Roman Studies* **70**: 101-125.

Horden, P. and N. Purcell (2000). *The Corrupting Sea*. Oxford, Blackwell Publishers.

Hough, E.C. (2004). The Financial Aspect of Growing Organic Wine Grapes in the Vredendal District (South Africa) http://www.farmingsuccess.com/organic.htm (accessed April 2006)

Houston, G.W. (2005). "Review of Michael MacKinnon. Production and Consumption of Animals in Roman Italy: Integrating the Zooarchaeological and Textual Evidence. Portsmouth, RI: Journal of Roman Archaeology, 2004." *Bryn Mawr Classical Review* **2005.10.15**

Hug (1953). In A. Pauly, G. Wissowa and W. Kroll (Eds.). *Real-Encyclopädie d. klassischen Altertumswissenschaft*. Volume 22.

Hutchinson, G.E., Ed. (1970). *Ianula: An Account of the History and Development of the Lago di Monterosi, Latium, Italy*. Transactions of the American Philosophical Society.

Ikeguchi, M. (1999/2000). "A Comparative Study of Settlement Patterns and Agricultural Structures in Ancient Italy: A Methodology for Interpreting Field Survey Evidence." *Kodai. Journal of Ancient History* **10**: 1-59.

Jarman, H.N. (1976). "The Plant Remains". In T.W. Potter (Ed.). *A Faliscan town in South Etruria. Excavations at Narce 1966-71*. London, The British School at Rome**:** 308-310.

Jashemski, W. (1979). *The gardens of Pompeii. Herculaneum and the villas destroyed by Vesuvius*. New Rochelle, New York, Caratzas Bros.

Jashemski, W.F. (1973). "Large Vineyard Discovered in Ancient Pompeii." *Science* **n.s.180**(4088): 820-830.

Jenkins, K. (1991). *Re-thinking History*. London, Routledge.

Jones, A.H.M. (1974). *The Roman Economy: studies in ancient economic and administrative history*. Oxford, Blackwell.

Jones, G.D.B. (1960). "Veii: the Valchetta baths." *Papers of the British School at Rome* **26**: 63-134.

--- (1962). "Capena and the Ager Capenas: part I." *Papers of the British School at Rome* **30**: 116-207?

--- (1963). "Capena and the Ager Capenas: part II." *Papers of the British School at Rome* **31**: 100-158.

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

--- (2003). "Slavery and the growth of Rome. The transformation of Italy in the second and first centuries BCE". In C. Edwards and G. Woolf (Eds.). *Rome the Cosmopolis*. Cambridge, Cambridge University Press**:** 100-122.

Jongman, W. and R. Dekker (1989). "Public intervention in the food supply in pre-industrial Europe". In P. Halstead and J. O'Shea (Eds.). *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge, Cambridge University Press**:** 114-122.

Judson, S. (1963). "Erosion and Deposition of Italian Stream Valleys During Historic Time." *Science* **New Series 140**(3569): 898-899.

Judson, S. and A. Kahane (1963). "Underground drainageways in Southern Etruria and Latium." *Papers of the British School at Rome* **18**: 74-99.

Kahane, A., L. Murray Threipland and J.B. Ward-Perkins (1968). "The Ager Veientanus, North and East of Veii." *Papers of the British School at Rome* **36**

Kamermans, H. (2000). "Land evaluation as predictive modelling: a deductive approach". In G. Lock (Ed.). *Beyond the Map. Archaeology and Spatial Technologies*. Ohmsha, Amsterdam, IOS Press.

--- (2004). "Archaeology and land evaluation in the Agro Pontino (Lazio, Italy)". In S. Holstrom, A.Voorrips and H. Kamermans (Eds.). *The Agro Pontino Archaeological Survey*. Leiden, Archaeological Studies, Leiden University (ASLU) 11.

Keay, S., M. Millett, S. Poppy, J. Robinson, J. Taylor and N. Terrenato (2000). "Falerii Novi: A New Survey of the Walled Area." *Papers of the British School at Rome* **68**: 1- 93.

Keppie, L.J.F. (1983). *Colonisation and veteran settlement in Italy: 47-14 B.C*. London, British School at Rome.

King, A.C. (1997). "Animal Bones". In T.W. Potter and A.C. King (Eds.). *Excavations at the Mola di Monte Gelato. A Roman and Medieval Settlement in South Etruria.* London, The British School at Rome**:** 383-403.

--- (1999). "Diet in the Roman world. A regional inter-site comparison of the mammal bones." *Journal of Roman Archaeology* **12**: 168-202.

King, A.C., P.A. Rhodes, K. Rielley and K.D. Thomas (1985). "I resti animali". In A. Ricci (Ed.). *Settefinestre. Una villa schiavistica nell'Etruria romana. La villa e suoi reperti. Vol. 3*. Modena, Edizioni Panini.

Kron, G. (2000). "Roman Ley-Farming." *Journal of Roman Archaeology* **13**: 277-287.

Lanciani, R. (1909). *Wanderings in the Roman Campagna*. London, Constable.

--- (1925). *Ancient and Modern Rome*. London, George G. Harrap & Co. Ltd.

Laurence, R. (1999). *The Roads of Roman Italy. Mobility and Cultural Change*. London, Routledge.

Lazer, E. (1995). *Human Skeletal Remains in Pompeii*. Unpublished PhD thesis, University of Sydney.

Lewin, R. (1983). "Isotopes Give Clues to Past Diets." *Science* **n.s.220**(4604): 1369.

Lewis, N. and M. Reinhold (1990b). *Roman Civilization: Selected Readings. Vol II: The Empire*. New York, Columbia University Press.

Lirb, H. (1993). "Partners in agriculture. The pooling of resources in rural societates in Roman Italy". In H. Sancisi-Weerdenberg (Ed.). *De Agricultura: In Memoriam Pieter Willem de Neeve*. Amsterdam, J. C. Gieben**:** 263-295.

Lloyd, J., N. Christie and G. Lock (1997). "From the mountain to the plain: landscape evolution in the Abruzzo. An interim report on the Sangro valley project (1994-5)." *Papers of the British School at Rome* **65**: 1-57.

Lo Cascio, E. (1994). "The Size of the Roman Population: Beloch and the Meaning of the Augustan Census Figures." *Journal of Roman Studies* **84**: 23-40.

--- (1999). "The Population of Roman Italy in Town and Country". In J. Bintliff and K. Sbonias (Eds.). *The Archaeology of Mediterranean Landscapes 1: Reconstructing Past Population Trends in Mediterranean Europe (3000 BC - AD 1800)*. Oxford, Oxbow Books**:** 161-171.

Lo Cascio, E. and P. Malanima (2005). "Cycles and stability: Italian population before the demographic transition (225 BC – AD 1900)." *Rivista di Storia Economica* **21**: 197-232.

Lock, G., T. Bell and J. Lloyd (2000). "Towards a Method for Modelling Surface Survey Data: The Sangro Valley Project". In M. Gillings, D. Mattingly and J. van Dalen (Eds.). *The Archaeology of Mediterranean Landscapes 3 : Geographical Information Systems and Landscape Archaeology*. Oxford, Oxbow Books**:** 55-63.

Luttrell, A. (1980). "Roman Anguillara". In K. Painter (Ed.). *Roman Villas in Italy. Recent excavations and research*. London, British Museum**:** 45-51.

Lyttelton, M. (1980). "The Mura di Santo Stefano near Anguillara: A Roman villa?" In K. Painter (Ed.). *Roman Villas in Italy. Recent excavations and research*. London, British Museum**:** 53-71.

MacKinnon, M. (1999). *Animal Production and Consumption in Roman Italy: integrating the Zooarchaeological and Ancient Textual Evidence*. Unpublished PhD thesis, University of Winnipeg.

--- (2001). "High on the Hog: Zooarchaeological, Literary, and Artistic Data for Pig breeds in Roman Italy." *American Journal of Archaeology* **105**(4): 649-674.

--- (2004a). "The role of caprines in Roman Italy: idealized and realistic reconstructions using ancient textual and zooarchaeological data". In B. Santillo Frizell (Ed.). *PECUS. Man and Animal in Antiquity. Proceedings of the Conference at the Swedish Institute in Rome. September 9-12 2002. Rome*, The Swedish Institute in Rome. Projects and Seminars.

--- (2004b). *Production and Consumption of Animals in Roman Italy: Integrating the Zooarchaeological and Textual Evidence*. Portsmouth, RI, Journal of Roman Archaeology.

Malone, C. and S. Stoddart, Eds. (1994). *Territory, Time and State. The archaeological development of the Gubbio Basin*. Cambridge, Cambridge University Press.

Malthus, T.R. (1798). *An essay on the principle of population : as it affects the future improvement of society / with remarks on the speculations of Mr. Godwin, M. Condorcet, and other writers*. London, J. Johnson.

Marcaccini, P. (1973). "Il limite dell'olivo nella Romagna e in genere nell'Italia continentale." *Rivista geografica italiana* **80**(1): 28-49.

Mason, S. (1995). "Acornutopia? Determining the Role of Acorns in Past Human Subsistence". In J. Wilkins, D. Harvey and M. Dobson (Eds.). *Food in Antiquity*. Exeter, University of Exeter Press**:** 12-24.

Mattingly, D.J. (1988a). "Oil for export? A comparison of Libyan, Spanish and Tunisian olive oil production in the Roman empire." *Journal of Roman Arcaheology* **1**

--- (1988b). "Megalithic Madness and Measurement. Or how many olives could an olive press press?" *Oxford Journal of Archaeology* **7**

--- (1994). "Regional Variation in Roman Oleoculture: some problems of comparability". In J. Carlsen (Ed.). *Landuse in the Roman Empire. Supplementum XXII. Rome,* "L'Erma" di Bretschneider Analecta Romana Instituti Danici**: 91-106.**

--- (1996). "First fruit? The olive in the Roman world". In G. Shipley and J. Salmon (Eds.). *Human Landscapes in Classical Antiquity. Environment and Culture*. London, Routledge**:** 213-253.

Meiggs, R. (1960). *Roman Ostia*. Oxford, Clarendon Press.

Mellor, R. (1999). *The Roman Historians*. London, Routledge.

Mills, N. (1981). "Luni: Settlement and Landscape in the Ager Lunensis". In G. Barker and R. Hodges (Eds.). *Archaeology and Italian Society. Prehistoric, Roman and Medieval Studies. Papers in Italian Archaeology II*. Oxford, BAR International Series 102: 261-268.

Milnor, K. (2005). *Gender, Domesticity, and the Age of Augustus*. Oxford, Oxford University Press.

Mommsen, T. (1868). *History of Rome*. Volume 1. London, Richard Bentley.

Moore, P.D., J.A. Webb and M.E. Collinson (1991). *Pollen Analysis*. Oxford, Blackwell Scientific Publications.

Mørch, H.F.C. (1994). "Agricultural Landscape: A Geographer's Considerations on the Past". In J. Carlsen (Ed.). *Landuse in the Roman Empire. Supplementum XXII. Rome*, "L'Erma" di Bretschneider Analecta Romana Instituti Danici**:** 107-112

Morea, S.J., J.-A.L.M. Lee, E.B. Lañadac, A.A. Taverosc and B.S. Cotiw-anb (1999). "Weight-for-age of growing pigs raised by smallholder farmers in the Philippines." *Preventive Veterinary Medicine* **41**(2-3): 151-169.

Moreland, J. (1987). "The Farfa Survey: a second interim report." *Archeologia Medievale* **14**: 33-43.

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

Muzzioli, M.P. (1980). *Cures Sabini. Forma Italia Regio IV 2*. Firenze, L.S. Olschki.

Naval Intelligence Division (1945a). *Italy*. Volume 1, Royal Admiralty.

--- (1945b). *Italy*. Volume 2, Royal Admiralty.

--- (1945c). *Italy*. Volume 3, Royal Admiralty.

Nesbitt, M. (2001). "Wheat evolution: integrating archaeological and biological evidence". In P.D.S. Caligari and P.E. Brandham (Eds.). *Wheat taxonomy: the legacy of John Percival*. London, Linnean Society**:** 37-59.

Netting, R.M. (1982). "Some Home Truths on Household Size and Wealth" In R.R. Wilk and W.J. Rathie (Eds.). 'Archaeology of the Household: Building a Prehistory of Domestic Life'. *American Behavioral Scientist*. **25:** 641-62.

NHS (2004). *Maintaining a Healthy Weight*, National Health Service http://www.nhsdirect.nhs.uk/innerpage.asp?Area=38 (accessed January 2004)

Nibby, A. (1837). *Analisi storico-topografico-antiquaria della carta de'dintorni di Roma*. Roma, Tipografia delle Belle Arti.

Nibby, A. and W. Gell (1820). *Le Mura di Roma*. Roma, V. Poggioli.

Nicolet, C. (1994). "Economy and Society, 133-43 B.C." In J.A. Crook, A. Lintott and E. Rawson (Eds.). *The Cambridge Ancient History. Volume IX: The Last Age of the Roman Republic, 146-43 B.C.* Cambridge, Cambridge University Press**.**

Niquet, H. (2000). "The Ideal of the Senatorial Agriculturalist and Reality During the Roman Republic and Empire". In K. Pollman (Ed.). *Double Standards in the Ancient and Medieval World*. Göttingen, Duehrkohp und Radicke**:** 121-133.

Nutton, V. (1995). "Galen and the Traveller's Fare". In J. Wilkins, D. Harvey and M. Dobson (Eds.). *Food in Antiquity*. Exeter, University of Exeter Press**:** 359-370.

O'Brien, P.K. and G. Toniolo (1991). "The poverty of Italy and the backwardness of its agriculture before 1914". In B.M.S. Campbell and M. Overton (Eds.). *Land, Labour and Livestock: historical studies in European agricultural productivity*. Manchester, Manchester University Press**:** 385-409.

Ogilvie, R.M. (1965). "Eretum." *Papers of the British School at Rome* **33**: 70-112.

Omodei Zorini, L. (2001). *Social and Economic Aspects*, Consorzio Olio Toscano http://www.consorziooliotoscano.it/ENG/contenuti/capitolo2.htm#inizio (accessed March 2006)

O'Neill, B.J. (1987). *Social Inequality in a Portuguese Hamlet: Land, Late Marriage, and Bastardy*, 1870-1978. Cambridge, Cambridge University Press.

Osborne, R. (1987). *Classical Landscape with Figures. The Ancient Greek City and its Countryside*. London, George Philip.

O'Shea, J. (1989). "The role of wild resources in small-scale agricultural systems: tales from the Lakes and the Plains". In P. Halstead and J. O'Shea (Eds.). *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge, Cambridge University Press**:** 57-67.

Packer, J.E. (1967). "Housing and Population in Imperial Ostia and Rome." *Journal of Roman Studies* **57**(1/2): 80-95.

Pallas, P. (1986). *Water for Animals*, AGL/MISC/4/85. Rome, Land and Water Development Division, Food and Agriculture Organization of the United Nations.

Pals, J.P. (1987). "Observations on the Economy of the Settlement". In W. Groenman-van Waateringe and L.H. van Wijngaarden-Bakker (Eds.). *Farm Life in a Carolingian Village: a model based on botanical and zoological data from an excavated site*. Maastricht, Van Gorcum**:** 118-129.

Parain, C. (1966). "The Evolution of Agricultural Technique". In M.M. Postan (Ed.). *Cambridge Economic History of Europe: Agrarian Life of the Middle Ages. Volume 1*. Cambridge, Cambridge University Press.

Parkin, T. (1992). *Demography and Roman Society*. Baltimore and London, The Johns Hopkins University Press.

--- (1999). "Clearing Away the Cobwebs: A Critical Perspective on Historical Sources for Roman Population History". In J. Bintliff and K. Sbonias (Eds.). *The Archaeology of Mediterranean Landscapes 1: Reconstructing Past Population Trends in Mediterranean Europe (3000 BC - AD 1800)*. Oxford, Oxbow Books**:** 153-160.

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., F. Di Gennaro, H. Di Giuseppe, S. Fontana, V. Gaffney, A. Harrison, S.J. Keay, M. Millett, M. Rendeli, P. Roberts, S. Stoddart and R.E. Witcher (2000). "The Tiber Valley Project: the Tiber and Rome through two millenia." *Antiquity* **74**: 395-403.

Patterson, H. and M. Millett (1998). "The Tiber Valley Project." *Papers of the British School at Rome* **66**: 1-20.

Patterson, J. (1987). "Crisis: What Crisis? Rural Change and Development in Imperial Apennine Italy." *Papers of the British School at Rome* **55**: 115-146.

--- (2004). "City, Territory and Metropolis: The Case of the Tiber Valley". In H. Patterson (Ed.). *Bridging the Tiber. Approaches to Regional Archaeology in the Middle Tiber Valley*. London, The British School at Rome**:** 61-74.

Pearson, K.L. (1997). "Nutrition and the Early Medieval Diet." *Speculum* **72**(1): 1-32.

Perini, R. (1982). "L'aratro dell'antica età del Bronzo del Lavagnone (com. Desenzano del Garda)." *Studi Trentini di Scienze Preistoriche* **61**

Porisini, G. (1971). *Produttività e agricoltura: i rendimenti del frumento in Italia dal 1815 al 1922*. Torino, Industria libraria tipografica editrice.

Potter, T.W. (1976). *A Faliscan town in South Etruria. Excavations at Narce 1966-71*. London, The British School at Rome.

--- (1979). *The Changing Landscape of South Etruria*. London, Paul Elek.

--- (1980). "Villas in South Etruria: Some comments and contexts". In K. Painter (Ed.) *Roman Villas in Italy. Recent excavations and research*. London, British Museum**:** 73-81.

Potter, T.W. and A.C. King, Eds. (1997). *Excavations at the Mola di Monte Gelato. A Roman and Medieval Settlement in South Etruria*. Archaeological Monographs of the British School at Rome No. 11. London, The British School at Rome.

Prowse, T., H.P. Schwarcz, S. Saunders, R. Macchiarelli and L. Bondioli (2004). "Isotopic paleodiet studies of skeletons from the Imperial Roman-age cemetery of Isola Sacra, Rome, Italy." *Journal of Archaeological Science* **31**: 259-272.

Purcell, N. (1988). "Review of A. Tchernia, Le vin de l'Italie Romaine: Essai d'Histoire Economique d'Apres les amphores. Rome 1986; and A. Carandini and A. Ricci eds. Settefinestre: Una Villa Schiavistica nell'Etruria Romana. Modena 1985." *Journal of Roman Studies* **78**: 194-198.

--- (1995). "The Roman villa and the landscape of production". In K. Lomas (Ed.). *Urban Society in Roman Italy*. London, UCL Press.

Quilici-Gigli, S. (1989). "Paesaggi storici dell'Agro Falisco: I prata di Corchiano." *Opuscula Romana* **17**: 122-135.

Rasmussen, T. (1991). "Tuscania and its territory". In G. Barker and J. Lloyd (Eds.). *Roman Landscapes:Archaeological Survey in the Mediterranean Region*. London, British School at Rome: 106 - 114.

Rawson, B. (2003). *Children and Childhood in Roman Italy*. Oxford, Oxford University Press.

Rawson, E. (1976). "The Ciceronian Aristocracy and its Properties". In M.I. Finley (Ed.). *Studies in Roman Property*. Cambridge, Cambridge University Press: 85-102.

Reggiani (1985). "La villa rustica nell'agro sabino". In. *Misurare la terra: centuriazione e coloni nel mondo romano. Città, agricoltura, commercio: materiali da Roma e del suburbio*. Roma, Panini: 61-65.

Reynolds, P.J. (1981). "Deadstock and Livestock". In R. Mercer (Ed.). *Farming Practice in British Prehistory*. Edinburgh: 97-122.

Richards, M.P., T.I. Molleson, J.C. Vogel and R.E.M. Hedges (1998). "Stable isotope analysis reveals variations in human diet at the Poundbury Camp cemetery site." *Journal of Archaeological Science* **25**(12): 1247-1252.

Richardson (1996). "Lugli, Giuseppe (1890-1967)". In N.T. de Grummond (Ed.). An *Encyclopedia of the History of Classical Archaeology*. London, Fitzroy Dearborn.

Rickman, G. (1980). *The corn supply of ancient Rome*. Oxford, Clarendon Press.

Ridgway, D. (1996). "Gell, Sir William (1777-1836)". In N.T. de Grummond (Ed.). *An Encyclopedia of the History of Classical Archaeology*. London, Fitzroy Dearborn.

Roberts, B.K. (1996). *Landscapes of Settlement. Prehistory to the Present*. London, Routledge.

Robinson, G.M. (1998). *Methods and Techniques in Human Geography*. Chichester, John Wiley and Sons.

Rosenstein, N. (2004). *Rome at War. Farms, Families, and Death in the Middle Republic*. London, University of North Carolina Press.

Rossi Doria, M. (1963). *Memoria illustrativa della carta della utilizzazione del suolo della Basilicata*. Roma, Consiglio nazionale delle ricerche.

Rostovtzeff, M. (1957). *The Social and Economic History of the Roman Empire*. Oxford, Clarendon Press.

Saaty, T.L. (1977). "A scaling method for priorities in hierarchical structures." *Journal of Mathematical Psychology* **15**: 234-281.

Sanders, T.A.B. (1999). "The nutritional adequacy of plant-based diets." *Proceedings of the Nutrition Society* **58**: 265-269.

Sansoucy, R., X. Alibes, P. Berge, F. Martilotti, A. Nefzaoui and P. Zoïopoulos (1983). *Olive by-products for animal feed*. Rome, FAO.

Sbonias, K. (1999). "Introduction to issues in demography and survey". In J. Bintliff and K. Sbonias (Eds.). *The Archaeology of Mediterranean Landscapes 1: Reconstructing Past Population Trends in Mediterranean Europe (3000 BC - AD 1800)*. Oxford, Oxbow Books**:** 1-20.

Scheidel, W. (1995). "The Most Silent Women of Greece and Rome: Rural labour and Women's Life in the Ancient World (I)." *Greece and Rome* **2nd series 42**(Oct): 202-217.

--- (1996). "The Most Silent Women of Greece and Rome: Rural labour and Women's Life in the Ancient World (II)." *Greece and Rome* **2nd series 43**(Apr): 1-10.

Schmidt, C.T. (1936). "The Italian "Battle of Wheat"." *Journal of Farm Economics* **18**(4): 645-656.

Schneider, P. (1969). "Honor and Conflict in a Sicilian Town." *Anthropological Quarterly* **42**: 109-29.

Sergeenko, M.E. (1952). *Vestnik Drevnei Istorii* **42**.

Shiel, R.S. (1991). "Improving soil productivity in the pre-fertiliser era". In B.M.S. Campbell and M. Overton (Eds.). *Land, Labour and Livestock: historical studies in European agricultural productivity*. Manchester, Manchester University Press**:** 51-77.

--- (1999). "Reconstructing Past Soil Environments in the Mediterranean Region". In P. Leveau, K. Walsh, F. Trément and G. Barker (Eds.). *The Archaeology of Mediterranean Landscapes 2: Environmental Reconstruction in Mediterranean Landscape Archaeology*. Oxford, Oxbow Books**:** 67-79.

Silverman, S. (1975). *Three Bells of Civilization: The Life of an Italian Hill Town*. New York, Columbia University Press.

Slicher van Bath, B.H. (1963). *The Agrarian History of Western Europe AD 500-1850*. London, Edward Arnold (Publishers) Ltd.

Small, A.M. and R.J. Buck (1994). *The excavations of San Giovanni di Ruoti*. Toronto; London, University of Toronto Press.

Smith, D. and E. Tetlow (2003). *The Insect Remains from the Roman Deposits at the Carlisle Millennium Site*, University of Birmingham Environmental Archaeology Services Report Number 53.

Soil Survey Division Staff (1993). *Soil survey manual*, Soil Conservation Service. U.S. Department of Agriculture Handbook 18.

Spivey, N. and S. Stoddart (1990). *Etruscan Italy*. London, B.T. Batsford.

Spurr, M.S. (1986a). *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.

--- (1986b). "Agriculture and the Georgics." *Greece and Rome* **33**(2): 164-187.

Steckel, R.H. (1995). "Stature and the Standard of Living." *Journal of Economic Literature* **33**(4): 1903-1940.

Sullivan, P. (2003). *Intercropping principles and Production Practices*, North Carolina Agricultural and Technical State University http://attra.ncat.org/attra-pub/intercrop.html (accessed January 2007)

Taylor, J. (2000). "Cultural depositional processes and post-depositional problems". In R. Francovich, H. Patterson and G. Barker (Eds.). *The Archaeology of Mediterranean Landscapes 5 : Extracting meaning from ploughsoil assemblages*. Oxford, Oxbow Books**:** 16-26.

Tchernia, Ed. (1986). *Le Vin de l'Italie Romaine: essai d'histoire économique d'après les amphores*. Bibliothèque des écoles françaises d'Athènes et de Rome 261. Roma, Ecole française de Rome.

Tennant, R. (1885). *Sardinia and its Resources*. Rome, Stanford, London & Spithöver.

Terrenato, N. (2004). "Sample size matters! The paradox of global trends and local surveys". In S.A. Alcock and J.F. Cherry (Eds.). *Side-by-Side Survey. Comparative Regional Studies in the Mediterranean World*. Oxford, Oxbow Books**:** 36-48.

The Commission of the European Communities (1985). *Soil Map of the European Communities at 1:1,000,000 (CORINE)*: GNV153, The Office for Official Publications of the European Communities, Luxembourg http://www.grid.unep.ch/data/ (accessed July 2003)

The Mackenzie Institute (1997). *Prohibition's Hangover. Ontario's Black Market in Alcohol* http://www.mackenzieinstitute.com/1997/1997_10_Sex_Alcohol.html (accessed April 2006)

Thompson, J. (1988). "Pastoralism and Transhumance in Roman Italy". In C.R. Whittaker (Ed.). *Pastoral Economies in Classical Antiquity*. 213-215.

Tomassetti, G. (1910-26). *La campagna romana: antica, medioevale e moderna.* Roma, Ermanno Loescher & Co.

Tomlin, R.S.O. (1998). "Roman Manuscripts from Carlisle: the Ink-Written Tablets." *Britannia* **29**: 31-84.

Toynbee, A.J. (1965). *Hannibal's Legacy: The Hannibalic war's effects on Roman Life. Volume II. Rome and Her Neighbours After Hannibal's Exit*. London, Oxford University press.

van Joolen, E. (2002). "Potential Land Evaluation in Archaeology". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 185-188.

--- (2003). *Archaeological Land Evaluation. A reconstruction of the suitability of ancient landscapes for various land uses in Italy focused on the first millennium BC*, University of Groningen http://www.ub.rug.nl/eldoc/dis/arts/e.van.joolen/ (accessed February 2004)

van Leusen, P.M. (2002). "Understanding Digital Archaeological Landscapes". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 125-152.

van Leusen, P.M. and H. Feiken (2001). "Interpreting field survey results in the light of historic relief change: the Fogliano beach ridges (south Lazio, Italy)". In Z. Stančič and T. Veljanovski (Eds.). *Computing Archaeology for Understanding the Past. CAA 2000. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 28th Conference, Ljubliana, April 2000*. BAR International Series 931. Oxford, Archaeopress**:** 205-210.

Verhagen, P. (2002). "Some Considerations on the Use of Archaeological Land Evaluation". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 200-204.

Verhagen, P., S. Gili, R. Micó and R. Risch (1999). "Modelling prehistoric land use distribution in the Rio Aguas valley (province of Almería, S.E. Spain)". In L. Dingwall, S. Exon, V. Gaffney, S. Laflin and M. van Leusen (Eds.). *Archaeology in the Age of the Internet. CAA97. Computer Applications and Quantitative Methods in Archaeology 25th Anniversary Conference, University of Birmingham*. BAR International Series 750. Oxford, Archaeopress**.**

Veyne, P. (1957). "La table des Ligures Baebiani et l' institution alimentaire de Trajan (Première article)." *Mélanges d'archéologie et d'histoire de l'École française de Rome* **69**: 81-135.

--- (1958). "La table des Ligures Baebiani et l' institution alimentaire de Trajan (Deuxième article)." *Mélanges d'archéologie et d'histoire de l'École française de Rome* **70**: 177-241.

Vita-Finzi, C. (1969). *The Mediterranean Valleys. Geological Changes in Historical Times*. Cambridge, Cambridge University Press.

von Thünen, J.H. (1966). *Der isolierte Staat* (Von Thünen's 'Isolated state': an English edition). Transl. C.M. Wartenberg. Oxford, Pergamon.

Walbank, F.W. (1957). *A Historical Commentary on Polybius*. Oxford, Clarendon Press.

Walker, D.S. (1967). *A Geography of Italy*. London, Methuen and Co Ltd.

Wallace-Hadrill, A. (1991). "Elites and trade in the Roman town". In J. Rich and A. Wallace-Hadrill (Eds.). *City and Country in the Ancient World*. London, Routledge**:** 244-277.

Walsh, K. (1999). "Mediterranean Landscape Archaeology and Environmental Reconstruction". In P. Leveau, K. Walsh, F. Trément and G. Barker (Eds.). *The Archaeology of Mediterranean Landscapes 2: Environmental Reconstruction in Mediterranean Landscape Archaeology*. Oxford, Oxbow Books**:** 1-8.

Ward-Perkins, J.B. (1962). "Etruscan Towns, Roman Roads and Medieval Villages: The Historical Geography of Southern Etruria." *Geographical Journal* **128**(4): 389-404.

--- (1970). "Monterosi in the Etruscan and Roman periods." In. *Ianula: An Account of the History and Development of the Lago di Monterosi, Latium, Italy*. **60:** 10-12.

West, B. (1997). "Bird Bones". In T.W. Potter and A.C. King (Eds.). *Excavations at the Mola di Monte Gelato. A Roman and Medieval Settlement in South Etruria*. London, The British School at Rome**:** 403-404.

Wheatley, D. (2004). "Making space for an archaeology of place." *Internet Archaeology* **15**.

Wheatley, D. and M. Gillings (2002). *Spatial Technology and Archaeology. The Archaeological Applications of GIS*. London and New York, Taylor and Francis.

White, C. (1980). *Patrons and Partisans: A Study of Politics in Two Southern Italian Communes*. Cambridge, Cambridge University Press.

White, K.D. (1963). "Wheat Farming in Roman Times." *Antiquity* **37**: 207-212.

--- (1965). "The Productivity of Labour in Roman Agriculture." *Antiquity* **39**: 102-107.

--- (1967). "Latifundia. A critical review of the evidence on large estates in Italy and Sicily up to the end of the first century AD." *Bulletin of the Institute of Classical Studies* **14**: 62-79.

--- (1967-68). "Virgil's knowledge of arable farming." *Proceedings of the Virgil Society* **7**: 9-22.

--- (1970a). *Roman Farming*. London, Thames and Hudson.

--- (1970b). "Fallowing, Crop Rotation, and Crop Yields in Roman Times." *Agricultural History* **44**(3): 281-290.

--- (1988). "Farming and Animal Husbandry". In M. Grant and R. Kitzinger (Eds.). *Civilization of the Ancient Mediterranean*. New York, Scribner's**:** 211-245.

White, R., V. Gaffney and H. Goodchild (2007).*Wroxeter, the* Cornovii *and the Urban Process. Final Report on the Wroxeter Hinterland Project 1994-1997. Vol. 1. Researching the Hinterland*. Portsmouth, RI, Journal of Roman Archaeology.

Whitehouse, D. (1980). "Anguillara: An introduction". In K. Painter (Ed.). *Roman Villas in Italy. Recent excavations and research*. London, British Museum**:** 111-117.

Wightman, E.M. (1981). "The Lower Liri Valley: Problems, Trends and Peculiarities". In G. Barker and R. Hodges (Eds.). *Archaeology and Italian Society. Prehistoric, Roman and Medieval Studies. Papers in Italian Archaeology II*. 275-287.

Wilson, A. (1994). "Water supply for Roman farms in Latium and South Etruria." *Papers of the British School at Rome* **62**: 139-196.

Witcher, R.E. (2005). "The Extended Metropolis: Urbs, Suburbium and Population." *Journal of Roman Archaeology* **18**: 120-138.

--- (2006). "Settlement and Society in Early Imperial Etruria." *Journal of Roman Studies* **96**: 88-123.

--- (in press). "The Middle Tiber Valley in the Early Imperial Period". In F. Coarelli and H. Patterson (Eds.). *Mercator Placidissimus. The Tiber Valley in Antiquity. New Research in the Upper and Middle Valley*. Rome, Quasar.

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.

Yntema, D. (2002). "Introduction: Advances in Regional Archaeological Research in the Mediterranean". In P. Attema, G.-J. Burgers, E. van Joolen, M. van Leusen and B. Mater (Eds.). *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*. BAR International Series 1091. Oxford, Archaeopress**:** 1-5.

Young, A. (1794). *Travels During the Years 1787, 1788 and 1789*. London, George Bell and Sons.

Zipf, G.K. (1949). *Human behavior and the principle of least effort: an introduction to human ecology*. Cambridge, Mass., Addison-Wesley Press.