

VISIBILITY AND THE LANDSCAPE: AN EXPLORATION OF GIS MODELLING TECHNIQUES?¹

INTRODUCTION

Several years ago I reviewed the use of line-of-sight or 'viewshed' analysis by archaeologists (Van Leusen 1999, revised and updated in Van Leusen 2002). Since then, viewshed studies have remained popular because they provide a relatively straightforward means of modelling aspects of past *cognitive* landscapes (as opposed to physico-economic landscapes). Visibility has been linked with control, even possession, of parts of the landscape, and relative degrees of visual control have been modelled using the cumulative viewshed index or CVI. Generally, researchers have sought to identify this and other viewshed properties that distinguish locations of archaeological interest (e.g. hillforts, barrows, rock art sites) from other locations in a landscape represented by a digital elevation model. However, little effort has so far gone into a better understanding of the method of viewshed analysis itself, and the assumptions underlying its use. In section 2 below, I first present a case study involving late Iron Age hillforts and early Roman military installations in central Shropshire, followed by a study of the hidden role of edge effects and viewshed parameters in this and similar work. The narrow application of line-of-sight tools available in most GIS by most practitioners has meant that several potential avenues of research have so far received little or no attention. In section 3 I present two case studies taken from my research in central and southern Italy, which suggest how a more qualitative use of viewshed properties could be used to look again at existing models of past societies. First, a review of Peroni's protohistoric settlement location model for the Sibaritide leads to the development of the contours of a method for viewshed-based landscape classification; and second, alternative explanations for the early historic Roman colonisation of the Lepine scarp are re-examined by looking at certain qualitative (landscape architectural) aspects of the colonial viewsheds.

CASE STUDY: THE WROXETER HINTERLAND

By way of an introduction to the topic of visibility and line-of-sight analysis, I will briefly explore the relations between visibility and control in the late Iron Age and early Roman landscape around the modern village of Wroxeter in central Shropshire (UK). Some aspects of the Iron Age – Roman transition within the territory of the local tribe of the Cornovii can be modelled using only the highest-ranked settlements of either period. Cornovian society is thought, especially in the later pre-Roman Iron Age, to have become increasingly sophisticated and to have been dominated by an aristocracy based on control over land, livestock, and mineral resources (especially salt). The region, some 1,200 square km of which was included in this study, contains more than 20 hillforts, most of which are presumed to date to the Iron Age although only a few have been investigated. This has been taken to indicate that the Cornovii were politically fragmented and were organised in local clans around chiefs. However, an alternative view maintains (White and Barker 1998:36) that the hillforts are in fact expressions of conspicuous consumption in a society that had few other outlets for its wealth.

Whichever the case may have been, certainly the hillforts would have functioned as places of refuge and control, and viewsheds from these hillforts may therefore tell us something about systems of control and defence in the pre-Roman Iron Age.

The land of the Cornovii was first invaded by the Romans in the late 40s AD, and the tribe seems to have come to terms with the conquerors without putting up significant resistance. Several temporary campaign forts were constructed in the area of Wroxeter, which controlled the main routes across the river Severn, in the following years. One of these is an auxiliary fortlet on the Severn just south of Wroxeter which may have secured the main Severn crossing; by the mid-50s the legionary fort at Wroxeter itself was established, probably by Legio XIII *Gemina* from Mancetter (Warwickshire). The early Roman military strategies may be studied via viewshed analysis of the legionary fortress at Wroxeter itself, and the auxiliary fort to its south. As the legionary fortress developed into a town and civil *civitas* capital after 30 years of predominantly military use, its viewshed may tell us much about its impact within a landscape that had never before seen a population centre of such size.

1 VISIBILITY AND CONTROL

We have prepared such an analysis for the Wroxeter study area by regrouping the traditional types of 'hillforts' and 'multivallate enclosures' into more meaningful sets of large (over 2 hectares) and small (less than 1.5 hectares) multivallate enclosures. The cumulative viewsheds of sites within these two groups demonstrate that the areas most intensively viewed are all in the central upper Severn valley and its main tributaries, with the maxima occurring on the western side of the Severn (Figure 1). As the site of Wroxeter itself is both well visible and near one of the main Severn fords, it was well suited to function as a (periodic?) trading post/market/fair in late Iron Age society, and forms a logical precursor to the legionary fortress and town.

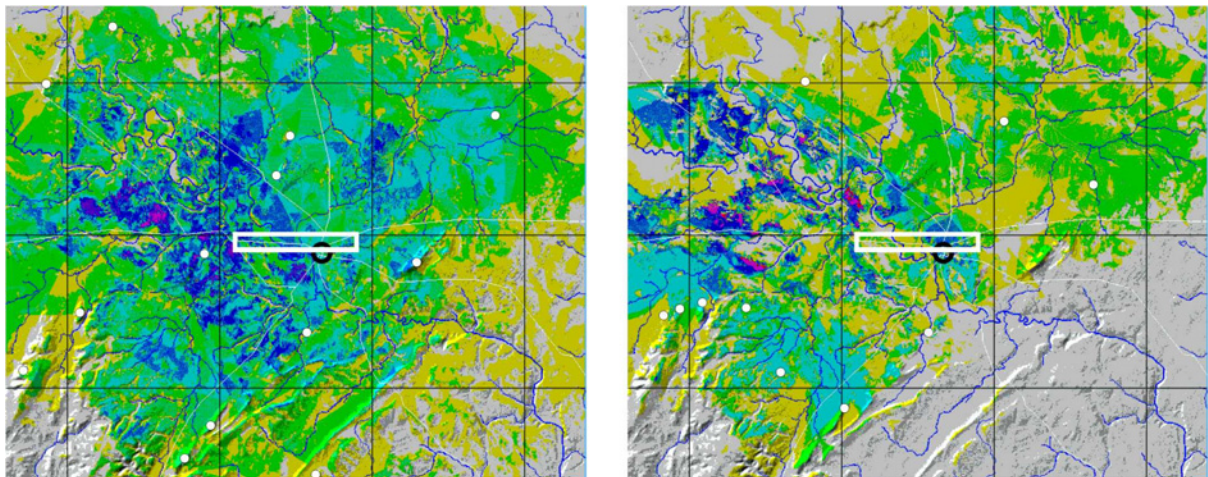


Figure 1: Cumulative 15km radius viewsheds of large (left) and small (right) multivallate enclosures (white dots) on a shaded DEM overlain with major streams and Roman road system (white lines). The 8 by 1 km box in the centre of the study area indicates the zone which does suffer from edge effects. Grid spacing: 10 km.

In a separate analysis, a multiple viewshed was calculated from Wroxeter in order to explore its relations with the known hillforts in the study area. In order to circumvent the problem of the low resolution (50 metres) DEM, the viewshed was calculated using the whole of the town walls as the seed area, and setting the viewing height at 5 metres (Figure 2a). The multiple viewshed for the legionary fortress preceding the town is essentially the same. Most of the hillforts within a 15 km radius, whether they were

occupied during this period or not, are found to lie within it. However, since hillforts that posed a threat to the Romans were forcibly abandoned after the conquest, it is not clear that these results have any significance beyond that which was already proven, namely that the location of Wroxeter was in common view and therefore a good 'neutral' place to hold markets. Roman military campaigns into the region used two major routes, one from Greensforge in south Staffordshire following the southern bank of the Severn, the other from Mancetter following the later Watling Street via Red Hill and curving north of the Wrekin. The precursor auxiliary fortlet to Wroxeter, discovered by aerial photography and subsequent partial excavations (St Joseph 1951, Houghton and Wells 1978), is located not on the elevated site of Wroxeter itself but nearly a mile to the south and some 15 metres lower right on the bank of the Severn. Given the military purpose served by this fortlet and the later legionary fortress, viewsheds based on them may well tell us which areas they were intended to control (see Figure 2B). As may be expected, the viewshed from the fortlet is smaller than that from the fortress. Whereas the fortress, like the later town, enjoyed an uninhibited viewshed over two-thirds of the compass, the auxiliary fort's view is limited to the western half the compass. What is more, the fortress viewshed nearly completely encompasses the fortlet viewshed, so whatever the reason was for placing the auxiliary fort where it is, it cannot have been the viewshed alone. We may therefore speculate that the fortress was placed directly on the riverbank for tactical reasons (campaigning across the Severn) rather than strategic ones (control of movement in the area).

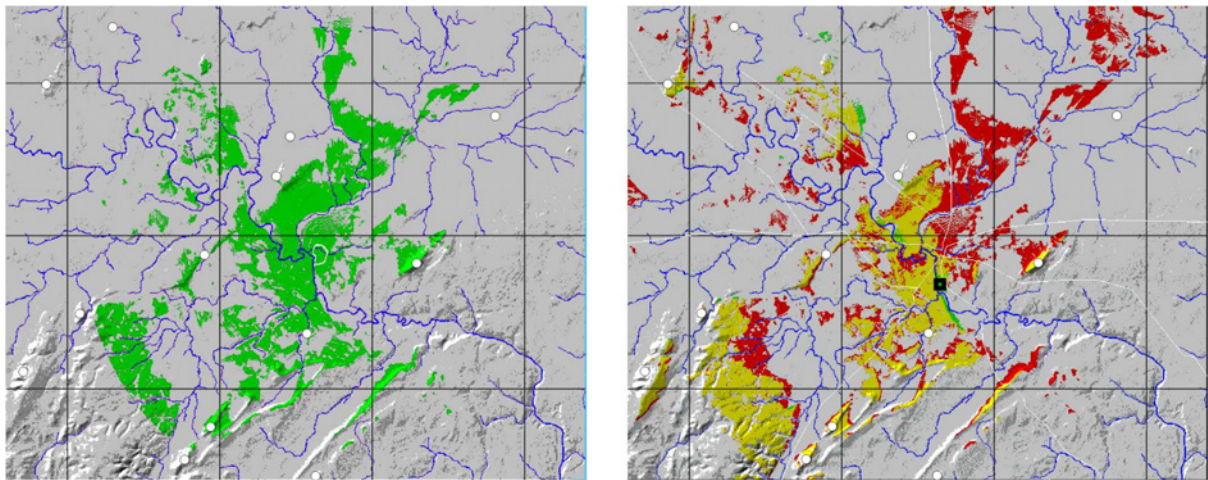


Figure 2, left: 15 km radius viewshed from the walls of Wroxeter. White dots: large multivallate enclosures. Right: the multiple viewshed from the fortlet (5m viewing height, green) is almost completely subsumed (yellow) into that from the fortress (7m viewing height, red). The partly reconstructed pattern of Roman roads is overlaid. Grid spacing: 10 km.

From Figure 2A it is not immediately clear how many of the 13 large multivallate enclosures within the study area fall within the Wroxeter viewshed. In fact, only 4 out of 13 are 'visible'. Field observations have shown this result to be incorrect for at least some of the hilltop locations, and point out a weakness in the line-of-sight technique employed: locations on the visible horizon are not reliably included in the viewshed. One possible technical solution (not pursued here) might be to expand the viewshed by the addition of 'horizon' cells. Such cells can be identified by the fact that they must a) lie next to cells that are within the viewshed, and b) be further away from the viewing point than any neighbouring viewshed cell.

Overlaying the partly reconstructed pattern of later Roman roads on these maps of indigenous hillforts, Roman military, and Roman civilian viewsheds, we can also observe that many sections of road fall within the viewsheds. However, this appears to be due to the generally favourable position of Wroxeter within the bowl-shape of the Severn valley

rather than to any conscious decision to build the roads in such a way that they would be visible from the fortress and town. Simulation studies presented in the next section will be used to argue that the statistical arguments generally adduced for deliberate placement of archaeological feature are weak (cf. Madry and Rakos 1996).

2 UNDERSTANDING VIEWSHED PROPERTIES

Cumulative viewshed analysis is a GIS tool often used to investigate and interpret the 'social' placement of archaeological sites and monuments in the landscape. The placement of these sites and monuments in areas of relatively high or (less often) low visibility is often seen as proof that they were *intentionally* put there. A more sophisticated approach would first calculate a 'background' cumulative viewshed index (or CVI) which describes the 'natural' visibility of all parts of the terrain, then investigate whether the viewshed properties of the sites of archaeological interest are significantly different from this. However, the quantitative study of viewshed intensity gives rise to several further more or less subtle distorting effects that must be taken into account. Two of these – the edge effect and the influence of viewshed radius on the relation between elevation and CVI - are demonstrated here.

EDGE EFFECTS

The edge effect has been discussed in general terms elsewhere (Van Leusen 1999, 2002:chapter 6), and in Figure 1 its maximum reach was visualised as a box outlined in red, but no attempt was made to quantify it. I will make such an attempt here, employing an idealised flat and circular raster 'world' with a radius of 40 cells; there are nearly 5,000 cells in this world. Three cumulative viewshed indices (CVI's) were generated using 50 (1 %), 250 (5 %), and 500 (10 %) samples of randomly chosen seed cells and a viewshed radius of 20 cells (see Figure 3). It may be observed that this relatively large viewshed radius yields a consistent area of high visibility near the centre of the world even with a very small sample of 'seeds'. As the number of seeds rises, so the CVI approximates the ideal distribution that would have resulted if we had calculated a cumulative viewshed index for all 5,000 cells. It is noteworthy that even a 5 % random seed sample can yield a CVI that deviates significantly from this ideal – so we cannot accept this as a rule of thumb (*contra* Lake et al. 1998) -, but the 10 % seed sample does produce a sufficiently idealised CVI for investigating the edge effect.

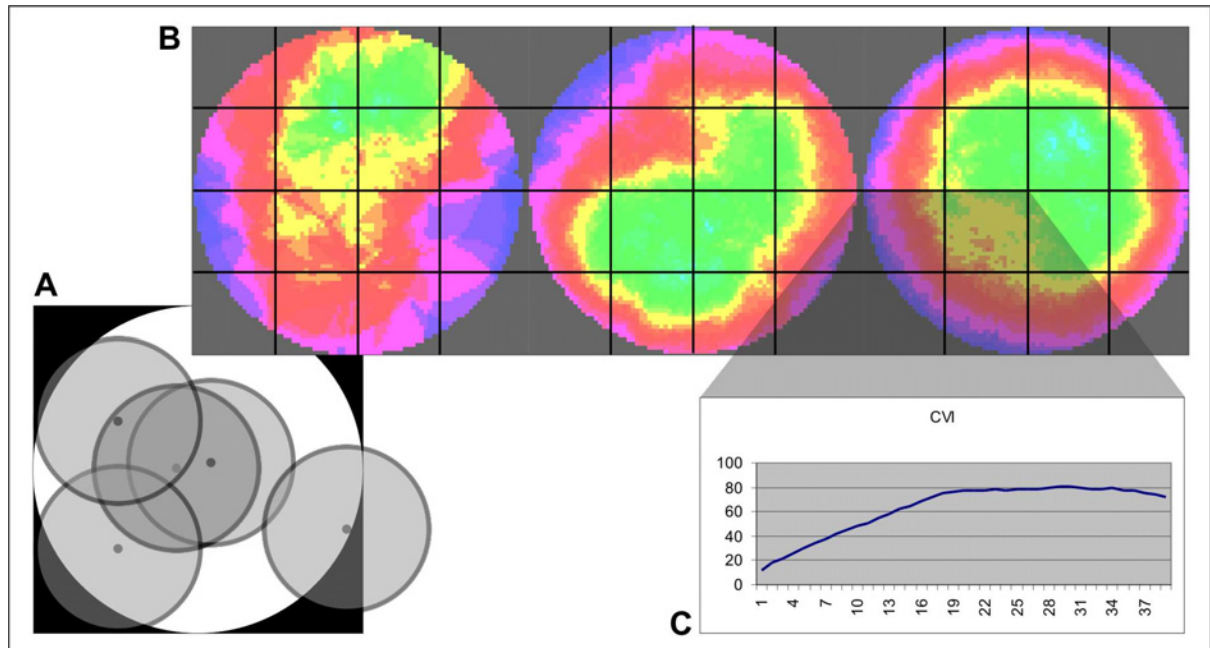


Figure 3: A, construction of a random Cumulative Viewshed Index (CVI). B: CVI's for a flat test universe of radius 40, using viewsheds of radius 20 and random samples of 50, 250, and 500 viewpoints. Min=magenta, max=green. Grid spacing: 20 cells. C: graph of edge distance (horizontal) against the normalised CVI (vertical) for the top right-hand universe. Above a distance of 20 cells (one viewshed radius), no edge effect occurs.

The three CVI images come progressively nearer the 'ideal', where all cells more than one viewshed radius (20 cells) from the edge have an identical CVI value. The relation between the median normalised CVI value and the distance from the edge of the world in cells for the top right-hand world in Figure 3 is represented in a graph. Within the circular and 'flat' universe used for this test, the edge effect diminishes linearly with distance, as predicted. With a 10 % sample of 'seed' cells, the normalised CVI value rises steadily from 12 % at the edge to 77 % at one viewshed radius from the edge, then holds steady at about 80% before dipping to 72 % at the centre of the universe due to the random nature of the seed cell locations.² The absolute CVI values at the edge of the universe and on the central 'plateau' depend on the precise combination of viewshed radius and average distance between seed points used. A formula could be derived to predict both, but in a viewshed study of a real terrain both parameters would obviously be significantly and unpredictably lowered.

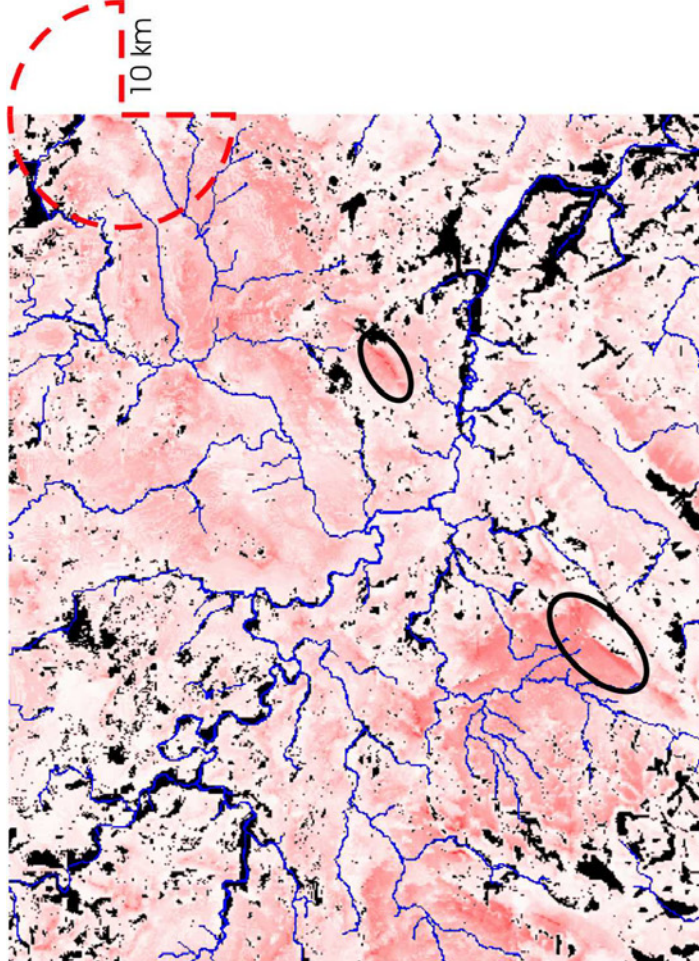
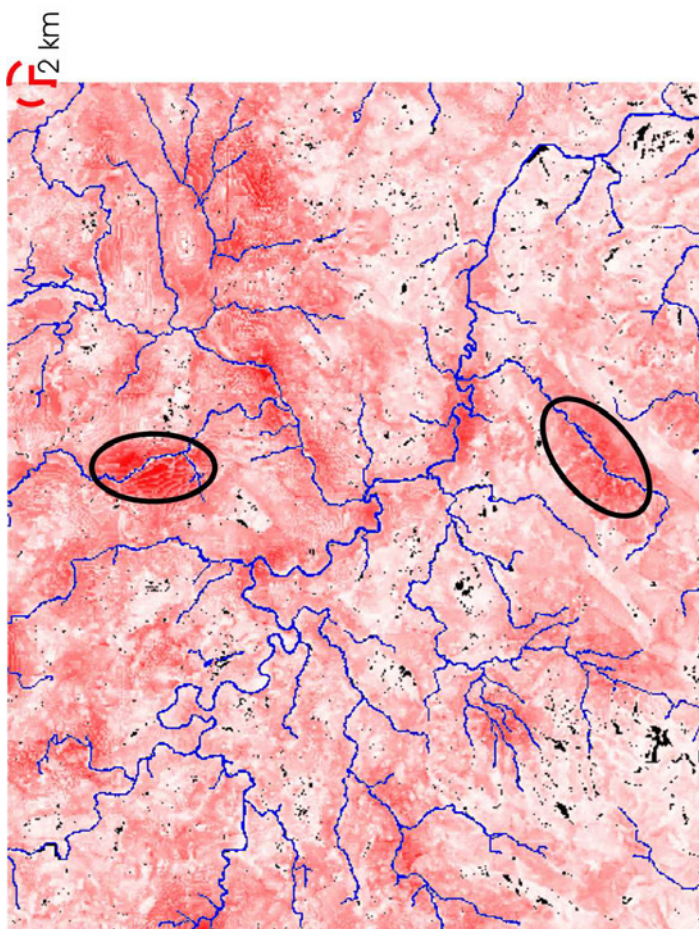


Figure 4: Background CVI's for the Wroxeter hinterland. Top: based on a ~1 % random seed sample of viewpoints, with a 2 km viewshed radius; Bottom: based on a ~0.1 % random seed sample of viewpoints, with a 10 km viewshed radius. Total number of cells in region: 471,000.

VIEWSHED RADIUS EFFECT

The further away from the viewer, the more likely it is that an object will be masked from view by intervening terrain, hence the more elevated it has to be in order to be seen. If we increase our viewshed radius, then the amount of visible terrain far from the viewer increases exponentially whereas the amount of visible terrain near the viewer remains constant; hence elevated locations will obtain a higher CVI value if larger viewshed radii are chosen. In order to investigate and demonstrate the effect of changing viewshed radius on the types of geomorphological units preferentially 'seen' under conditions of changing viewshed radii, digital elevation data from the Wroxeter study area were used to calculate several random 'background' CVI's at varying radii. This showed up some important effects straight away: the cumulative short-range (2 km) viewshed generated from a set of 5,000 points (Figure 4 left; approximately 4 points per km²) contains visibility values ranging from 0 (completely secluded) to 54 (highly visible), but these are not randomly distributed. In fact, they correlate directly with the size of the convex and concave geomorphic units in the study area, especially when these are larger than an individual viewshed (say, over 4 km²). Conversely, a cumulative long-range (10 km) viewshed generated from 500 points (Figure 4 right; approximately 1 point per 6 km²) shows that the high CVI values correlate with prominent ridges and hillsides, an effect which would be expressed even more strongly if, as is current practice in many GIS studies, the viewshed radius were unconstrained.



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CASE STUDIES: ITALY

The late protohistoric (Late Bronze Age/Early Iron Age) settlement pattern in much of Italy has been interpreted as one indicative of the transition of pastoral ways of life to one dominated by agriculture and increasing hierarchisation of society, culminating in the rich graves of Iron Age elites and in evidence for early urbanisation in many regions but apparently developing first in Etruria and Lazio. Late protohistoric centralised settlement has been interpreted as evidence of a territorial division in which each settlement laid claim to essential landscape resources, with an initial phase of peer polity interaction being followed by one in which a single settlement obtained hegemony and others are relegated to second rank. The further development of this system seems to have been aborted in the south in the Late Iron Age and the Archaic/Classical period when economic life re-oriented on the successful colonies of Greek origin; in central Italy it was the hypertrophy development of Rome which disturbed the equilibrium. The locations of what have been regarded as the upper-rank settlements are generally described as 'dominant', expressing their elevated, easily defensible positions and large viewsheds within which essential landscape resources such as transhumance routes were located. This opens up the possibility of studying the viewshed properties of these settlement systems and the landscape that they are part of.

In order to explore further the issues raised in this introduction, two case studies are presented here. The first presents a protohistoric and pre-colonial case regarding accessibility, visual contact, and territorial structure in the Sibaritide (northern Calabria); the second a case of the Roman colonial landscape in the Pontine region (south Lazio). The hierarchisation of protohistoric settlement systems on the basis of size and location characteristics is examined with reference to Peroni's (1994) models for southern Italy, and the role of strategic considerations in the location of early Roman strong-points in the Pontine region is considered through an investigation of 4th century BC colonies on the Lepine scarp, in the context of Livy's historical references.

1 SETTLEMENT AND TERRITORY IN PROTOHISTORICAL SOUTHERN ITALY

The current model for protohistoric settlement and territorial development in southern Italy is provided by Peroni (Peroni 1994, Peroni and Trucco 1994), who also provides a list of habitation and cemetery sites (see Figure 5). For the Middle Bronze Age (1600 - 1300 BC) there are ca. 17 of these, for the Recent Bronze Age (1300 - 1150 BC) ca. 19, and for Final Bronze Age/Early Iron Age (1150 - 900 - 700 BC) ca. 38. As shown in Figure 5, in the Middle Bronze Age the Sibaritide foothills - marine and fluvial terraces consisting of sands and conglomerates - are thought to have been in use for cereal cultivation and some cattle breeding; in the Recent Bronze Age land use may have shifted back toward pastoralism tending toward higher elevations, mainly in the interior, a tendency continuing in the Final Bronze Age. In the Early Iron Age new settlements emerge mainly in the interior, possibly for strategic reasons but this may also be related to a stronger emphasis on agricultural territory. Peroni (1994:fig. 96) suggests that in this period peer polities developed as well, most of which controlled territories incorporating sections of the plain, foothills, and upland.

Underlying Peroni's phase maps is a site type classification by D'Angelo and Oràzie Vallino (in Peroni and Trucco 1994:827-8), who established the following classes for protohistoric settlement in the Sibaritide:

1. settlement and cultivable land in a well-defended area
2. elevated sites in protected conditions, but with little cultivable space - hence suitable for small communities only

3. settlement in a well-defended position, but with cultivable unprotected land nearby – some suitable for large communities, some for small
4. settlement and cultivation possible, but only limited natural defences present
5. sites with properties mainly useful for pastoralists
6. sites whose main function lies in their viewsheds

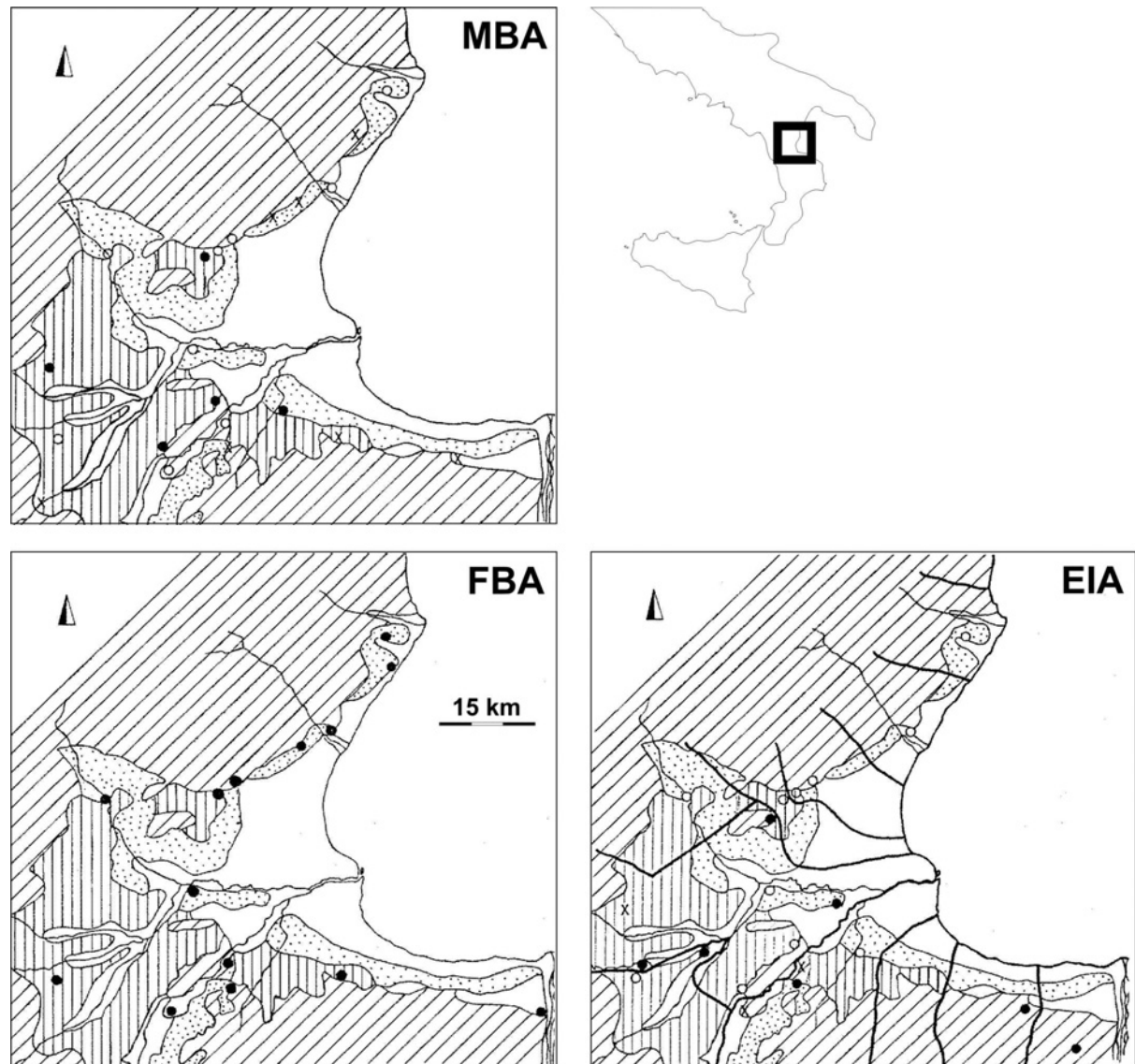


Figure 5 - Protohistoric site distributions in relation to lithotypes, after Peroni 1994:figs. 83, 86, and 96. Top left: Middle Bronze Age subsistence economy. Bottom left: Final Bronze Age animal husbandry. Bottom right: Early Iron Age territories. Open circle: site continued from previous period; closed circle: new site; cross: site discontinued from previous period. Oblique hatching: lithoid formations; Vertical hatching: non-terraced sands and conglomerates; Stippling: terraced sands and conglomerates suitable for crops; Blank: recent sediments.

The total number of sites by class is as follows: class 1: 10; class 2: 10, class 3: 4; class 4: 4; class 5: 7; class 6: 6. Classes 1 and 3 would contain the top-ranked settlements, classes 2 and 4 are minor centres, and 5 and 6 are special purpose sites. Note that the class boundaries are ambiguous: the difference between classes 1 and 4 is in the quality of the natural defences, that between 1 and 3 in the presence of cultivable land outside rather than inside the defences, and that between 2 and 6 (presumably) in the quality of the viewsheds. In all this, it must be remembered that the actual archaeological evidence from many of these sites can be as little as a handful of shards. On the basis of

the distribution of these site types in the landscape, pairs of settlements occupying single hill systems have been identified, consisting of one larger settlement situated at lower altitude and with sufficient agricultural land nearby, and one smaller defensible settlement at a higher altitude. An example of the former type is the site of Monte S. Nicola, occupying the saddle and sides of two hills overlooking both the coastal plain and the valley of the Raganello river at an altitude of about 500 m asl. If we assume that the protohistoric settlement pattern was largely based around a pastoral land use pattern (with transhumance route between summer and winter pastures following the radial ridges and streams of the Sibaritide, and valleys forming obstacles rather than routes), then sites such as Monte S. Nicola should have certain viewshed characteristics. In particular, the locations of any hilltops should be favoured from which, when coming from the upland summer pastures, winter pasture in the plain first comes into view. We can model such locations by calculating viewsheds from several points in the plain.

ZONES OF VISUAL CONTACT

The general context for Peroni's models of protohistoric settlement systems is provided by the physiography of the Sibaritide, in particular its radial geomorphology and hydrography. Within such a landscape, areas with similar viewshed properties can be modelled without having recourse to the locations of known sites and using 'background' visibility properties instead. Such areas can be defined by simple criteria and can be organised hierarchically, for example:

- all locations from where a significant part of the coastal plain or the major valley floors can be seen; this includes the plain and valleys themselves, the edges and slopes of terraces, and the higher slopes of the Pollino and Sila ranges which face the plain
- all locations from where no part of the plain or valley floor can be seen; this includes the highlands, secondary river valleys, and the interior of the terraces

To explore such a model, four unrestricted viewsheds were calculated for points lying on the coastline at the mouths of the Raganello and Crati rivers and at two other points to the north and south, plus seven more viewsheds of 10 km radius based on four points located on the plain along the base of the foothills and three points within the major valleys of the Coscile and Crati rivers. When combined, these 11 viewsheds do indeed define the intended visual zones (see Figure 6). By including known protohistoric settlements in this model, their degree of association with single zones or, conversely, their liminality with respect to these zones can be assessed and interpreted. Liminal sites should be located near the edge of a visual zone but still within the visible area. Protohistoric sites that lie on the outer edge of zone B can be interpreted as essentially inland sites situated as close as possible to the coastal plain; protohistoric sites that lie on the outer edge of zone C might be related to transhumance routes and the point where these begin to descend into the plain; sites on the inner edge of zone C are 'foothill' sites situated for visual control of the largest possible area of the coastal plain; and sites that lie within the secluded parts of zone C are 'plain' (presumably agricultural) sites with no significant viewshed characteristics. A first inspection of the model presented in Figure 6 suggests that it might indeed be possible to group protohistoric sites according to such viewshed properties; a better controlled and more detailed study will, however, be necessary to substantiate this.

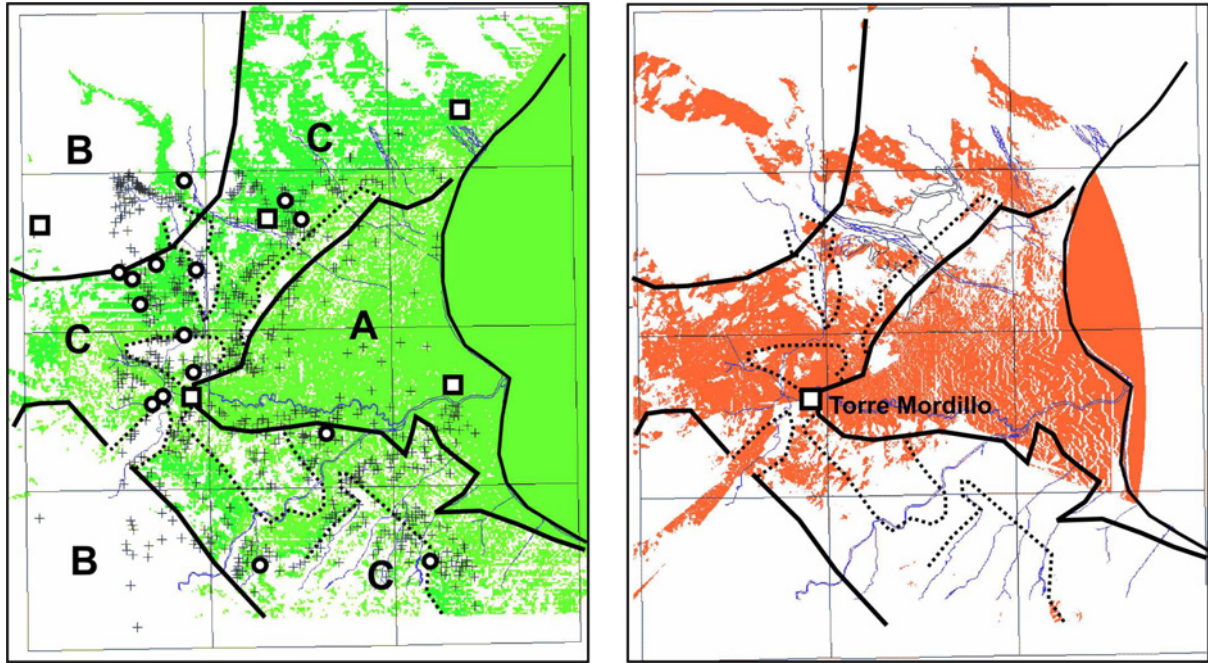


Figure 6 - Left: Visual Zones of the Sibaritide. A: coastal plain and lower slopes, B: highland zone, no visual contact with the plain, C: foothill zone with areas of visual isolation (dotted lines: terraces and valleys). Squares/circles: major/minor protohistoric sites. Plus signs: Hellenistic/Roman sites. Grid lines represent the boundaries of IGM topographic map sheets of the 1:25,000 series. Right: 25km radius viewshed from the important protohistoric settlement site of Torre Mordillo.

The utility of the concept of visual zones can be further explored by comparing them to the viewsheds of individual protohistoric sites. The right-hand map in Figure 6 presents one such viewshed, calculated from the site of Torre del Mordillo, which was probably the most important indigenous settlement at the time of the first Greek colonisation by reason of its size and commanding position on a plateau overlooking the confluence of the Crati and Coscile rivers. It can be seen that the site has a very large viewshed, covering both the coastal plain and much of the major inland valley floors and slopes. Because of its relatively elevated position on the rim of a marine plateau, its viewshed also includes some of the 'secluded' areas not visible from locations in the plain and valley bottoms. The significance of these zones that tend to be 'hidden' from most of the plain and valleys (or conversely, from where these areas cannot be seen; indicated by dotted lines in Figure 6) could be further explored.

2 ROMAN COLONIES ON THE LEPINE SCARP

As the influence of Rome over affairs in southern Latium grew in fits and starts during the Archaic and post-Archaic period (6th to early 4th centuries BC), and intermittent conflict with neighbouring tribes became more disruptive, the development of the indigenous Latial peer-polity system of city states was superseded by that of a core-periphery system. The Pontine plain became the scene of a drawn-out conflict between the expanding early Roman state and the rather less clearly defined, but equally expansive, hill tribes, and later that of Roman demographic and agricultural expansion. Attema (1993:231) suggested that the early Roman colonies of Cora, Norba, and Setia may have played an important role in the later Republican 'colonisation' of the Lepine side of the Pontine plain. The presence in this area of a large number of so-called 'platform' villas which appear to be of very similar date and design argues, he wrote, for a planned process of agricultural re-organisation and exploitation, probably targeted at the production of olive oil and grain for the Roman market³. The position of the colonies themselves on the rim of the Lepine (pre-Apennine) mountains, with magnificent views

across the Pontine plain to the sea and along the coast as far north as Antium and as far south as the Monte Circeo, in this model expresses the control exercised over this agricultural area.

However, the towns of Norba, Cora, Setia and others already existed long before the late Republican period, and in order to understand why they are located on the Lepine margin we have to trace their origins as far back as we can. From the ancient historians, foremost of which is Livy's *Ab Urbe Condita*, we gather that no historic evidence predates the very end of the 6th century BC; that none of the towns mentioned was actually *established* by colonisation from Rome; and that most or perhaps all were therefore pre-existing indigenous Archaic and probably (by analogy with other areas) Iron Age settlements. Late Iron Age and Archaic hilltop settlements such as certainly existed at Norba and Cora were populated by a patchwork of indigenous lowland and highland tribes-people, apparently maintaining some kind of political equilibrium punctuated by low-level raiding, presumably for cattle and prestige (see also examples cited in Attema, in press). This would explain why these settlements were located in places which afforded both safety and control over land and cattle.

Starting in the late 6th century BC, groups of Roman colonists were apparently sent out in an opportunistic manner to safeguard Rome's political and military interests. The towns of the Lepine margin, 'outposts' from the viewpoint of Rome, bore the brunt of her conflicts with the Volscan tribes that lasted throughout the 5th and the first half of the 4th century BC. More than once, the allegiances of these towns swerved from safety under Roman hegemony to independence from heavy-handed Roman rule; some Latial tribes even continued to raid each other's territories, as is shown most clearly by the case of Privernum which, from its southerly position may have felt itself to be as much akin to the Volscan way of life as it was to that of the Latial League. While the objectivity of Livy's accounts may be questioned, it seems clear that the conflict between Latins and Volscans is acted out on the medium term, the *conjoncture* as defined by Braudel, and can be understood perhaps in terms of the upland boom-bust cycle cited by Bintliff (1997:30-32). Most of the Lepine margin must have been effectively incorporated into the Roman state by the mid-4th century when, in 358 BC (VII, 15) she added the Pomptine and Publilian tribes – territorial units in which citizens were enrolled for census, taxation, and military levies – and, following the final defeat of the Privernates and the settling of their territory with colonists, the Oufentine tribe in 329 BC. By the end of the 4th century the military Via Appia was completed as far south as Anxur/Terracina. The platform villas identified by Attema (1993) appear only after this *de facto* incorporation into the Roman state was completed.

In view of the above, the long-term Roman 'policy' may not have been to *establish* colonies on the Lepine margin, but to ensure that the important indigenous Archaic central places became or remained allied to her, an allegiance that could at times be strengthened by sending out colonists for reasons as much to do with demographic pressure at Rome as with strategic interests (providing early warning and protection from Volscan raiding parties and containing a local population which could not be trusted to choose Rome's side in a conflict). It is not unlikely that both sets of factors combined to determine which 4th century sites were deemed to be most important.

VIEWSHED ANALYSIS

The 4th century BC Roman colonies of the Lepine scarp provided bases from which both agriculture and husbandry in the plain and uplands could be protected from Volscan inroads. But they also acted as visual manifestations of Roman power in the lands of her former Latial allies. Their viewsheds might therefore include areas in both the plain and the upland; especially the Lepine mountain passes from which raiding parties might arrive. At the same time they must be located sufficiently close to valuable cropland and

grazing herds to be able to protect these against sudden attack. Hence, if we model viewsheds for these colonies we must take into account upland characteristics such as the location of mountain passes as well. Higuchi viewsheds were recently introduced in archaeological research by Wheatley and Gillings (2000) as a way of enriching traditional viewshed studies. Amongst other characteristics, Higuchi proposed that viewsheds should contain information about the *distance* and *bearing* to the objects in view. With respect to distance, Higuchi viewsheds are subdivided into a short range (< 360 m) sector in which objects are individually distinguishable and have a direct sensory impact, a middle range (360 - 6,600 m) sector which constitutes the 'pictorial' landscape where vision is paramount, and a long range (> 6,600 m) sector which contains the 'vertical backdrop' and horizon features. The distances at which each of these sectors begin and end are variable, because they are relative to the typical tree size for the area under study, but in the following description of Higuchi properties of the three Lepine colonies I simply use Wheatley and Gillings' ranges. Their middle range viewsheds are depicted in Figure 7.

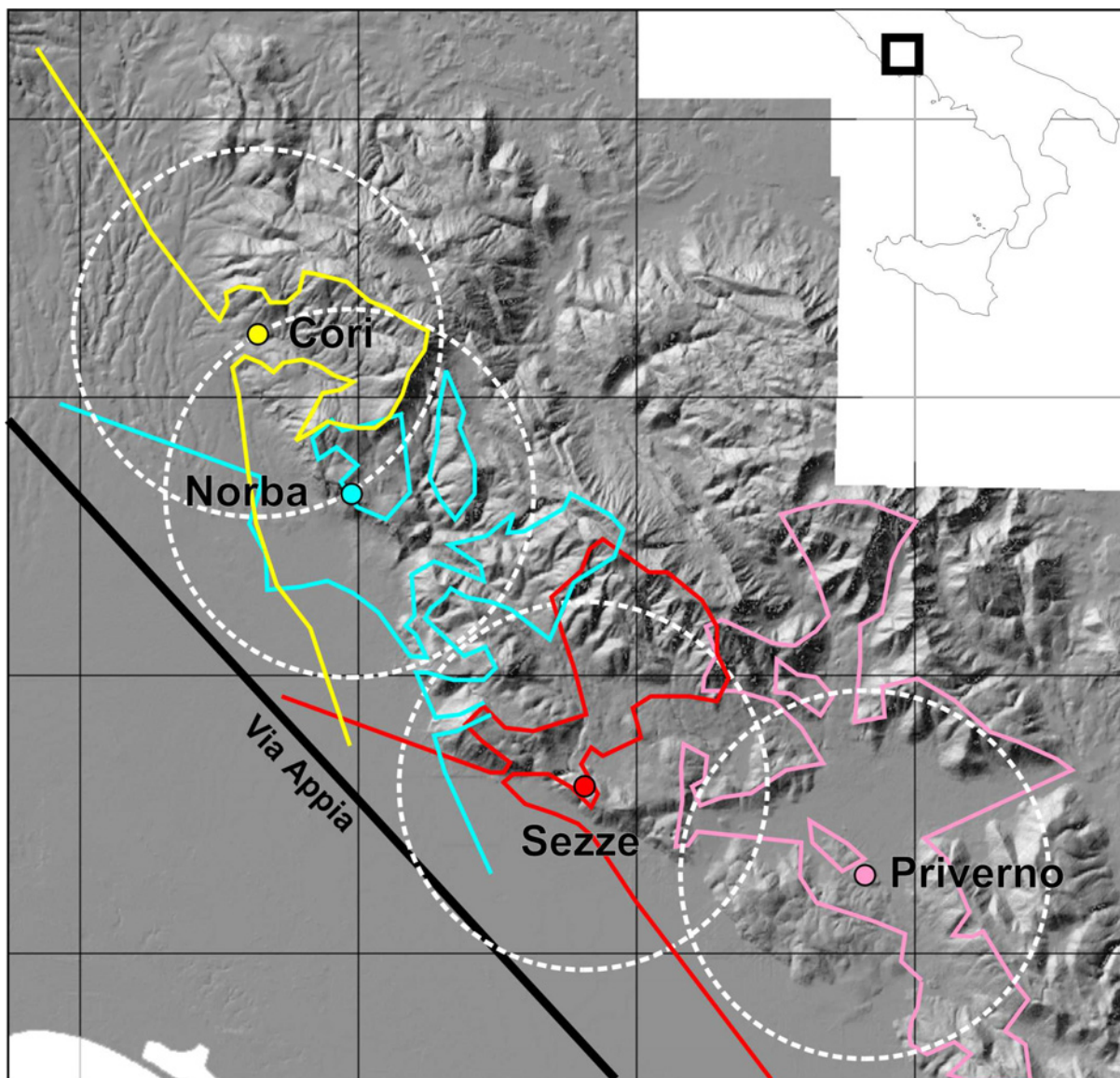


Figure 7: Higuchi viewsheds of the three Roman colonies at Cori, Norba, and Sezze, and of the protohistoric centre at Priverno on a shaded elevation model of the Lepine mountains. The Higuchi radius of 6600 m is indicated by the dashed circles. Grid spacing: 10 km.

Cora is located on the western rim of the Lepine mountains, where they border on the volcanic landscape of the Alban hills, on top of a small hill situated at the mouth of a small drainage basin (391 m asl). Its views to the north and southeast are obstructed by neighbouring higher hills. The whole of the Alban massif and the Pontine plain as far as Monte Circeo over 45 km to its south can be seen from Cora, and its direct hinterland, up to 6 km distant, is also relatively well covered. The Roman colony of Norba is situated on a promontory of the Lepine scarp, with steep slopes on three sides but open to the interior, where several small streams and their tributaries drain a modest agricultural hinterland before descending into the plain. The highest point on this promontory, the 'acropolis' hill, is at 490 m asl. The viewshed taken from this approximate point, which is located almost 600m from the Lepine scarp, is especially large toward the east and south-east, and again the view across the Pontine plain includes both Monte Circeo and the Alban hills. However, from this location one cannot see the nearby footslopes and river valleys. Since field observations have shown that long stretches of the lower Lepine slopes are visible from its perimeter wall, an improved Norba viewshed model should clearly be based on multiple viewpoints along its perimeter. Setia is located on a small hill next to the place where the Fosso Brivolco descends into the plain, at about 280 m asl, and is naturally protected on all sides by steep slopes. A viewshed taken from the approximate location of its central church extends into the upper valley of the Brivolco and into the pass leading east past Roccagorga, all within 5 km of the town. There is no viewshed due east. Toward the sea, there is an almost 180 degree unrestricted view taking in the Pontine plain and coastal landscape, with the Monti Ausoni and Monte Circeo at up to 30 km distance as a backdrop; however, views in both directions along the Lepine scarp are restricted by the hills directly to the west and east, and the characteristic shape of the Alban massif is not visible from the town.

The most easily accessible route between the Pontine plain and other parts of Italy to the east and southeast is through the Lepine mountains via the valleys of the Amaseno/Oufente. These valleys are surrounded by several hilltop settlements probably dating back to the Iron Age: Roccasecca dei Volsci, Maenza, Roccagorga and Priverno among them. A viewshed from Privernum was used to set off the other three views. It turns out that all of the major valleys here can be seen very well from this location, even up to the pass between the Lepine and Ausonic mountains, leading south-east to Campania. There is no view into the Pontine plain and, possibly significantly, no significant visible upland within the Higuchi distance which the Romans might have needed to control by the installation of a colony following the siege and capture of Privernum in 330 BC.

Summing up, each of the three colonies has an excellent view of the plain, including both the Via Appia and the centuriated agricultural zone along it, but the viewsheds do not indicate that the lower Lepine slopes and the ancient *pedemontana* route along it were of immediate concern. Toward the hinterland the colonial viewsheds are complementary and mutually exclusive (that is, together they cover the whole of the western side of the Lepine mountains, but they do not overlap); these viewsheds, and the fields and pastures within them, are mostly within the Higuchi distance of 6600 m and would therefore have afforded strong visual control over the whole area. The hypothesis that the 4th century BC Roman colonization in the Pontine region was originally mainly strategic in nature is therefore upheld.

CONCLUSIONS

The case studies presented here no longer represent the 'state of the art' in GIS modelling of visibility, which has moved on since the late 1990s. Archaeologists' interpretation of visibility models is now informed by a better understanding of statistical complexities, and the limitations of the underlying theory are beginning to be understood. Further work will be needed in order to develop sufficient understanding of 'background' visibility indices such as the one presented here. Of equal importance is the testing of GIS-generated models, firstly by a comparison with extant historic, archaeological, and cartographic data, and thereafter by targeted fieldwork.

Although the simulations presented in section 2.2 do not constitute conclusive proof, it would appear that simply by increasing the viewshed range used, the higher visibility values will concentrate on areas of higher ground, ridges and peaks. Any sufficiently large sample of archaeological viewpoints will tend to generate a cumulative viewshed similar to these simulated ones, depending on the viewshed radius used. Furthermore, any such viewshed based on points located on or near ridges and peaks will further emphasise the visibility of other ridges and peaks. These results, together with those obtained in similar simulation studies that found little correlation of viewshed intensity with elevation (Franklin and Ray 1994), clearly need further evaluation. Cumulative viewshed analyses must take such effects into account, or they become little more than the means by which we illustrate our *a priori* convictions.

The case studies presented in section 3 demonstrate that current economic and cognitive models of the ordering of settlements and the landscape in protohistory (and, in the case of indigenous societies, for many centuries afterwards) are of a very non-specific and intuitive nature. Bias modelling and corrective fieldwork will be needed to test the many (often unspoken) assumptions that underlie these models. Current typologies of protohistoric settlements in central and southern Italy are insufficiently clear, detailed, or supported by evidence to allow the definition of hierarchical and contemporaneous levels with any degree of certainty. The basis for constructing territorial divisions, whichever method is chosen for it, is therefore lacking. By comparison, Rome's early colonies were intended to fulfil strategic functions, so their locations meet other criteria of dominance – namely that of control over routes of attack and advance. The fact that the viewsheds of the Roman colonies on the Lepine margin are both complementary and fall within the Higuchi 'medium range' distance creates support for the idea that these towns were located as much to control movement across the Lepine up- and highlands, as to control and protect communications and agricultural resources in the Pontine plain.

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¹ This article is abridges and revised from chapters 15 and 16 of my PhD thesis (Van Leusen 2002). Two of the three case studies presented here were originally developed in the context of the study of Romanisation and urbanisation in the Wroxeter Hinterland, an area centring on the modern-day village of Wroxeter in the middle Severn valley (Shropshire, UK). For an introduction to the Wroxeter Hinterland project, see Van Leusen 2002:chapter 3); aspects of centralisation and Romanisation in the Wroxeter hinterland have been sketched elsewhere by White and Van Leusen (1997) and again by White and Barker (1998).

² A normalized CVI value of 100 % is theoretically possible, but will only occur if the viewshed radius is equal to or larger than the world radius.

³ It now appears from recent field work that the majority of these platform villas were built in the 3rd century BC; hence they can have no direct link to the 4th century colonisation of the Pontine plain.