The rural landscape of Neopalatial Kythera: a GIS perspective

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Postprint of 2002 paper in *Journal of Mediterranean Archaeology* 15.2: 217-256 (doi: 10.1558/jmea.v15i2.217).

Abstract

Intensive archaeological survey on the island of Kythera (Greece) has revealed, in unprecedented detail, a landscape of dispersed rural settlements dating to the mid-second millennium BC. This paper deploys a series of GIS and spatial analysis techniques to illuminate the way this landscape was structured, in terms of social organisation, agriculture and island demography. Discussion begins by quantifying site numbers, size and hierarchy. It then examines patterns of settlement dispersal, highlighting the subsistence strategies probably underpinning such a landscape. Emphasis is placed on reconstructing where possible the dynamics of colonisation and the motivations behind site location. A final section proposes population figures for the island and considers a range of site-level interactions.

1. Introduction

This paper engages with the space-time dynamics of a particular prehistoric Mediterranean countryside. It combines a variety of GIS-driven techniques with the results of intensive archaeological survey. Over the last 10 years, there has been an increasing interest in the Mediterranean rural past (e.g. Doukelis and Mendoni 1994; Barker and Mattingly 1999-2000; Horden and Purcell 2000). Research has embraced many academic disciplines, including demography, climatology, geomorphology, ethnography and archaeology, but has frequently occurred under the umbrella of intensive landscape survey. In the Aegean, this has resulted in a host of analyses, including synthetic discussions (van Andel and Runnels 1987; Halstead and Frederick 2000), and period-specific investigations. Amongst the latter, the Neolithic (Cherry *et al.* 1988; Perlès 2001), Classical-Roman (Lohmann 1992; Alcock 1993; Jameson 1994; Acheson 1997; Whitelaw 2000; Pettegrew 2001; Raab 2001), Medieval (Stedman 1996) and modern (Whitelaw 1991; Jameson *et al.* 1994; Halstead and Jones 1997; Sutton 2000) rural landscapes have all received attention. In comparison, and despite a large number of excavated and surveyed sites, the Middle-Late Bronze Age, the Aegean's 'palatial' age, is still woefully under-analysed in this respect, perhaps partly as a result of a traditional preoccupation with Bronze Age palaces and towns.

Recent detailed research on the island of Kythera (The Kythera Island Project, hereafter KIP) provides an excellent opportunity to remedy this situation and to highlight a range of spatial analysis techniques that would be widely-applicable to other Mediterranean regions and periods. Kythera lies some 15 km off the southern tip of the Peloponnese (Figure 1). Its size (ca. 278 sq km) and position have often made it an important stepping-stone between the distinctive geographical and cultural areas of the Greek mainland to the north and Crete to the south-east. It can be characterised as a modern semi-arid Mediterranean landscape, a relatively diverse and highly-fragmented environment. In modern times, its human inhabitants have concentrated on agriculture rather than maritime or industrial activities and the island has been subject to quite dramatic fluctuation in its population and level of material prosperity. As such, Kythera represents a rich setting in which to study the pattern and process of rural life, as affected by ecology, historical contingency and its islanders' own strategies and concerns.

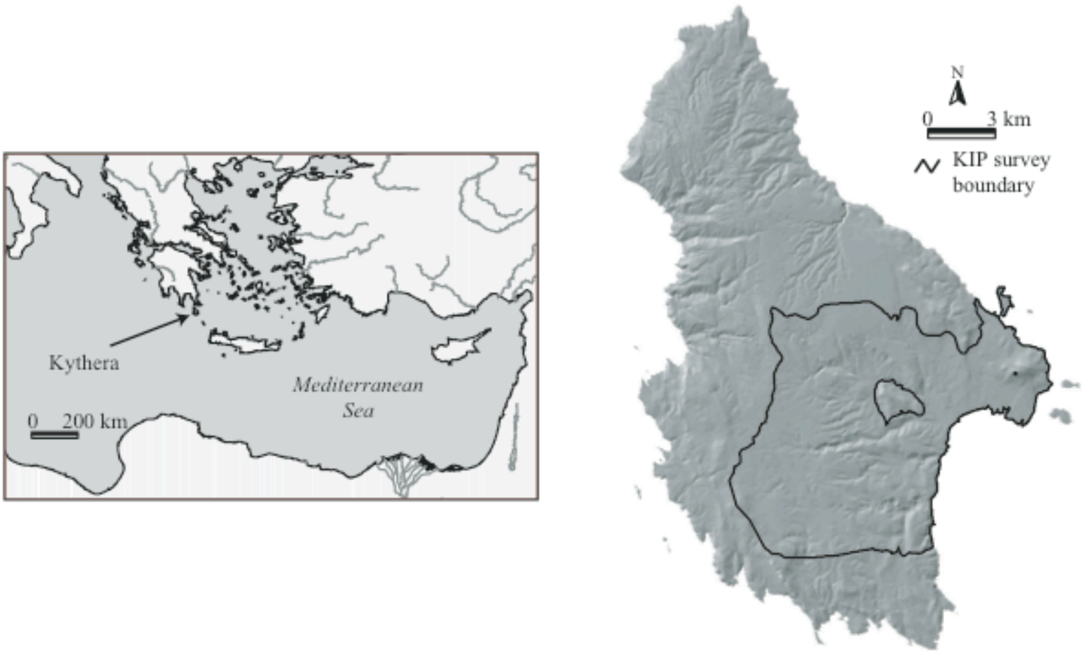

Figure 1. Kythera

The focus here is on the Kytheran landscape of the mid-second millennium BC. Finds of this period were first identified on the island by Benton (1931-2: 245-46) who noted tombs and ceramics of Cretan 'Neopalatial' type in and around the Kastri headland on the eastern coast of the island and a single sherd from the Agia Sophia cave in the south.[1]

Subsequent survey and excavation (Waterhouse and Hope Simpson 1961: 148-60; Coldstream and Huxley 1972) has done much to articulate the existence of a harbour town at Kastri. But until recently very little new light has been shed on the nature of Neopalatial occupation, if any, beyond this site (though possible Late Minoan [LM] I material in both tomb and apparent adjacent settlement contexts was also noted at Lioni [Staïs 1915; Waterhouse and Hope Simpson 1961: 149-50]).

[1] The Neopalatial Period (Middle Minoan III-Late Minoan I, hereafter MMIII-LMI) falls in the middle of the second millennium BC The precise absolute chronology is heavily debated: even so, both 'high' (ca. 1750-1525/1490 BC: Manning 1999: 335-40, fig.62) and 'low' (1700/1650-1425 BC: Warren and Hankey 1989: table 3.1) versions suggest a duration of two and a half to three centuries.

However, intensive survey by KIP between 1998-2001 has identified a further 80+ sites (Figure 2) that can be clearly dated to the same period by reference to diagnostic coarseware fabric types (see Broodbank 1999: 212-13, fig.9; Kiriatzi 2003) and that have benefited from unprecedented level of detailed surface collection and geoarchaeological attention. This now constitutes an incomparably rich dataset to look at a range of site-level dynamics, not least settlement hierarchy, dispersal and location. Moreover, from the beginning of KIP fieldwork, information has been collected and organised within a GIS environment (Bevan and Conolly n.d.) and this data-structure supports a variety of important insights. The chronological range for these sites is two and a half to three centuries, but probably less in most cases, since many can be dated exclusively to the Late Minoan I period (ca. one and half centuries) or even to a late part of this phase (Kiriatzi 2003). As such, they represent a relatively shallow temporal palimpsest and can be treated as a meaningful contemporary landscape.

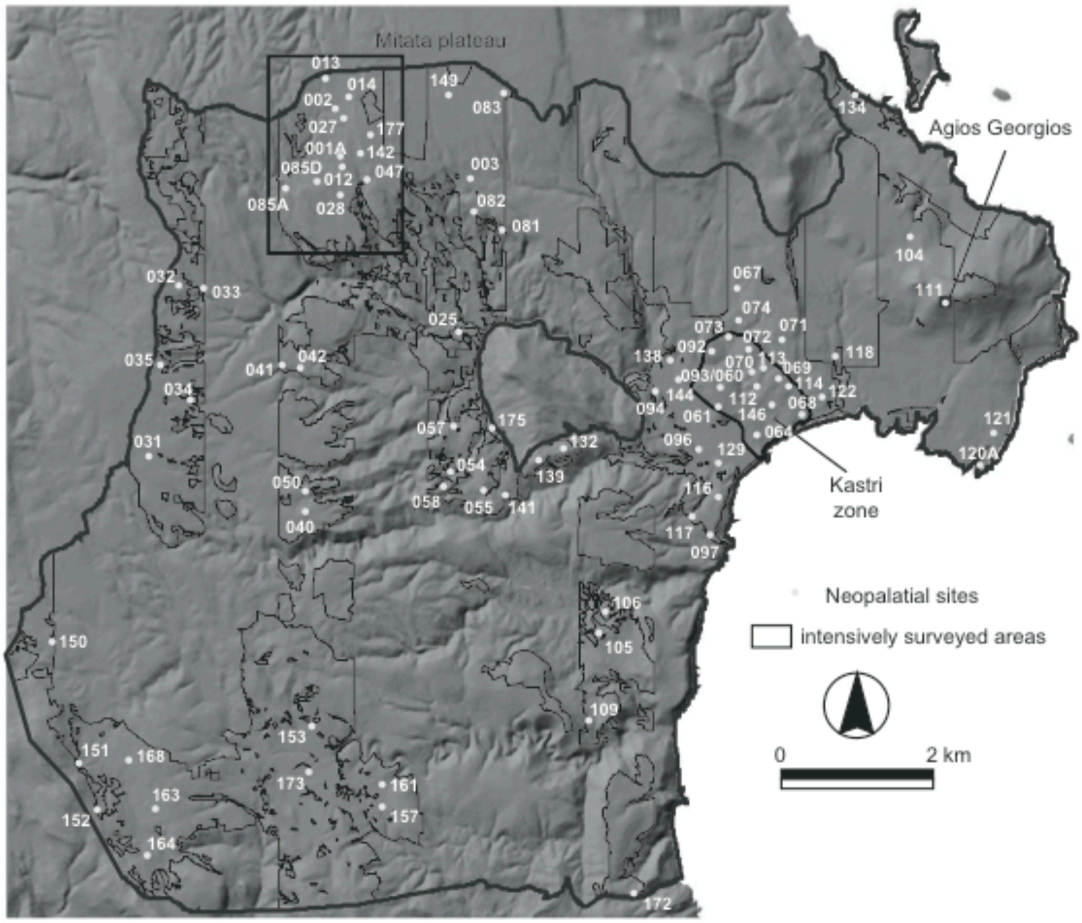

Figure 2. Neopalatial sites and the Kythera Island Project intensive survey

The following discussion is divided into four parts. The first section looks at site visibility, numbers and size, both around the urban centre at Kastri and in the rural hinterland. The second concentrates on the rural landscape and examines site spacing, ceramic distributions in and around the main scatters, and probable land holdings and possible subsistence strategies within the context of a dispersed settlement pattern. The third section moves on to consider whether we can identify any deliberate preferences motivating the way rural sites were located and concentrates on two particularly useful approaches (terrain ruggedness and hydrology). The fourth and final section deploys evidence from the previous sections to suggest a model of island demography and explores a range of probable site-level interactions.

2. Site Numbers, Size and Hierarchy

The existing corpus of 80+ Neopalatial sites on the island is a sample and should be treated as such. Any attempt to reconstruct settlement dynamics on this basis must firstly contend with a) how sites have been defined and b) how representative this resulting sample is of the rest of the island.

A great deal of attention has been paid to the question of site definition in landscape survey (e.g. Cherry 1983: 394-97; Dunnell and Dancy 1983; Carman 1999): it has by now become evident that if the term 'site' is to be used at all (which many survey archaeologists dispute, particularly for the material landscapes left by non-sedentary societies), then methods of definition should be made explicit and due attention must be paid to the position of site foci within a broader, continuous landscape of human activity. On Kythera, we retained the concept of the site: when explored at the scale of 5 sq m vacuum circles, single-period Neopalatial site scatters typically produce a mean/median density of 0.4-1 sherds/sq m. However, such quantifiable surface signatures are both scale-dependent (e.g. the size of the observation units and the time spent on them) and geomorphologically-dependent (e.g. relatively stable limestone plateau vs. heavily dissected marl valley), and it would be inappropriate to adopt any given density index as a qualifying criterion. Rather, KIP site definition was an explicitly multi-stage process, progressing through a) tract-walking, b) initial revisitation, c) geoarchaeological investigation and d) gridded site collection. Initial assessments were deliberately optimistic and were narrowed down on the basis of subsequent visits. At least three of the four stages above were involved in the characterisation of almost all KIP sites and for the estimates of scatter size and location used in this analysis. Moreover, as will become clear, Neopalatial Kythera is a specific cultural landscape in which, fortunately, we can be particularly comfortable in our definitions of 'on-site' and truly 'off-site' activity.

The KIP survey area (Figs. 1-2) covers a central portion (some 35.7%) of the island, including the hinterland of the Bronze Age centre at Kastri. Within this survey area, terrain was sampled in sub-hectare tracts by surveyors spaced 15 m apart; over 8,700 tracts were surveyed, covering some 4,255.7 ha (42.8% of the wider survey area, 15.3% of the island), with tract size and shape defined arbitrarily in undivided terrain of similar visibility/vegetation or, where appropriate, following local land use or cultural units (median tract size = 3,825 sq m). This 'intensively tract-walked' sample area is used repeatedly in the following analysis as a zone of relatively complete and consistent coverage in statistical terms, in which 66 definite rural Neopalatial sites and 14 more from the area around Kastri were found (three sites found during extensive reconnaissance beyond this area have been excluded).

Within this sample, we need to assess how likely it is that sites have been missed or have not been preserved. Indeed, the impacts of ground surface visibility and a range of geomorphological factors on the make-up of the site sample pose, as ever, serious challenges to landscape archaeology. However, they themselves are open to statistical analysis and GIS-led modelling. Some of these issues have been explored in detail elsewhere (Bevan and Conolly n.d.) and contrary to expectation, the KIP data shows no clear, predictable pattern between surface ceramic density and surface visibility at either large (sub-hectare tracts) or small (5 sq m vacuum circles) observation scales. More importantly for our purposes here, sites were as likely to be identified in areas of poor visibility as in good visibility. In other words, our sample does not seem to be strongly affected by such simple *ground surface* visibility issues.

However, the transmission of sub-surface archaeological remains into surface assemblages is definitely biased by a range of post-depositional processes that do not occur uniformly over the landscape. Terraces, for example, can either expose archaeological material or conceal it, depending on the way they are constructed (Frederick and Krahtopoulou 2000): in other words, their effect on site visibility is highly unpredictable on the basis of their mere presence alone. Likewise, general erosion and sedimentation processes in Mediterranean landscapes are complex and require careful geoarchaeological investigation. Such research is on-going on Kythera and will provide a very nuanced understanding of the impact of these processes on archaeological preservation in the surveyed area. Limited areas certainly need to be treated with caution, because they have been either covered with alluvium or dissected by winter-season floods since the Bronze Age. However, in contrast to regions such as Boeotia (Bintliff *et al.* 1999), we can afford to be optimistic about the survival of whole micro-landscapes on Kythera, especially in areas of low slope and little recent intervention. For example, the upland plateau region near the modern village of Mitata (Fig. 2) will feature repeatedly in this analysis as a remarkably-well preserved prehistoric landscape. Moreover, except in the specific problematic areas mentioned above, re-visitation (e.g. by geoarchaeologists or re-survey after seasonal fires have burnt away the vegetation) leads us to be confident that, under Kytheran conditions, no extant major site and only a few minor sites will have been missed, *within the tract-walked area*. Furthermore, a combination of extensive survey, excavation and chance finds over the past century or so suggests strongly that no Neopalatial centre on the scale of Kastri exists elsewhere on the island.

The level of attention given to Neopalatial sites within the KIP survey area has made it possible to be quite precise about the extent of the *in situ* surface scatter (which in most examples has only been subject to low-energy taphonomic processes), which in turn provides a basis for reliable estimates of site size. As mentioned above, the vast majority were not only intensively fieldwalked, but also subjected to careful gridded collection. In addition, many were specifically examined with respect to how their immediate geoarchaeological environment might reveal both patterns of local resource exploitation (e.g. quarries, water sources, possible cross-channel terraces) and the impact of geomorphology on site integrity.

A chart of all known Neopalatial sites shows that the variety of scatter sizes is actually quite limited (Figure 3). Indeed, when we look closer at the *spatial* distribution of the Neopalatial sites this hierarchy of settlement sizes appears even flatter, for two reasons: firstly, Kastri seems to exert a metropolitan attraction on neighbouring sites, as almost all of the variation in scatter size occurs quite close to the port centre (Figure 4). Indeed, it may be inappropriate to speak of a discrete 'site' at Kastri at all (especially given the fact that Neopalatial tombs and settlement debris are found interspersed in the area: Bevan *et al.* 2002), but rather a larger patchwork landscape of habitations, tombs and perhaps agriculture in a broad region (hereafter called the 'Kastri zone'), bounded by the (probable) Palaiopolis inlet on the south side and scatters to the north and west (Figure 5). (At least in terms of the patchiness of the settlement evidence beyond the core of the site, this pattern is similar to the one found at Palaikastro in eastern Crete, though it is less clear in the latter case whether this relates to actual settlement patterning or to localised geomorphology and surface visibility MacGillivray and Sackett 1984; Whitelaw 2001: 22, fig. 29.g]).

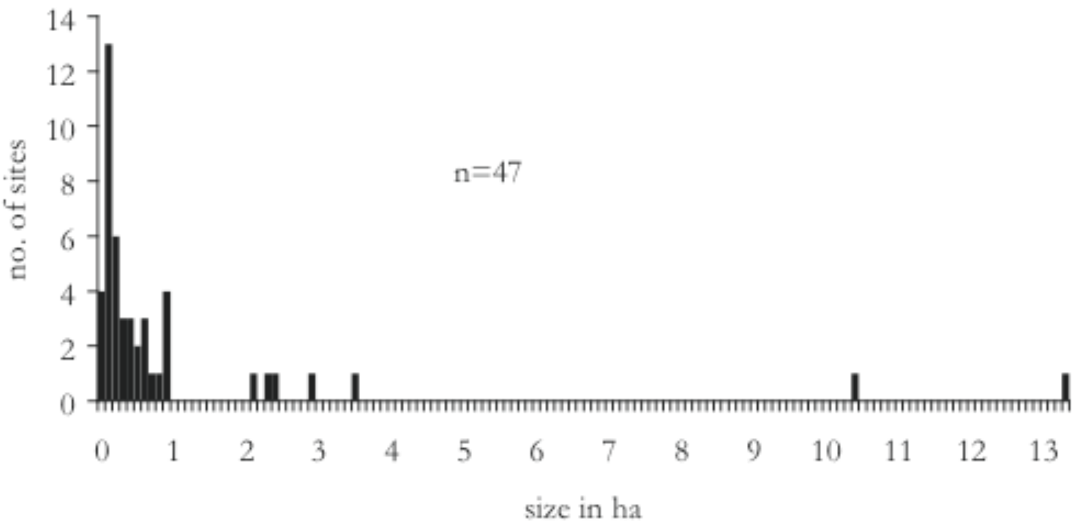

Figure 3. Neopalatial scatter sizes. (N.B. another ca. 35 sites do not yet have estimated areas, but appear to be 0.1-0.3 ha.)

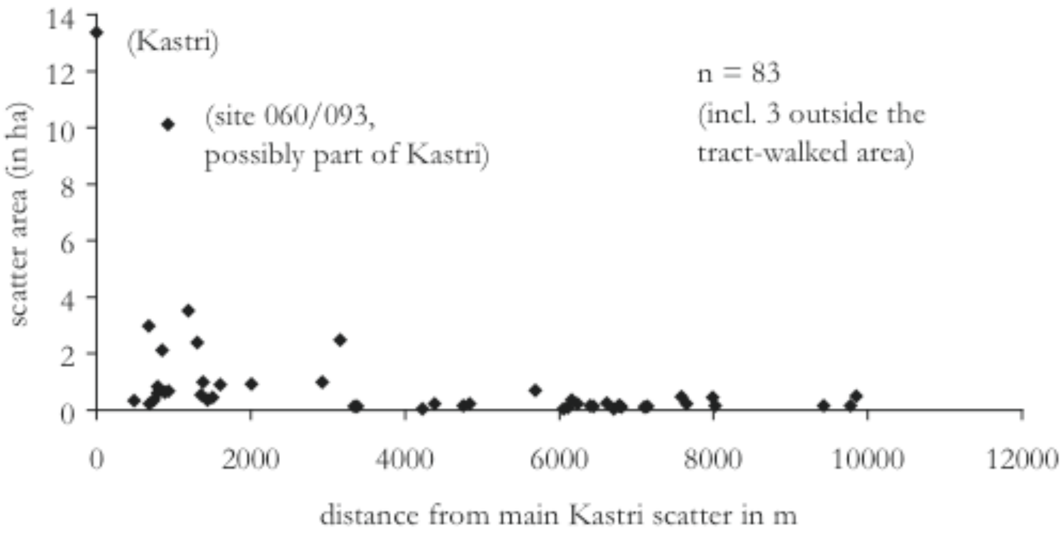

Figure 4. Neopalatial scatter size and distance from Kastri

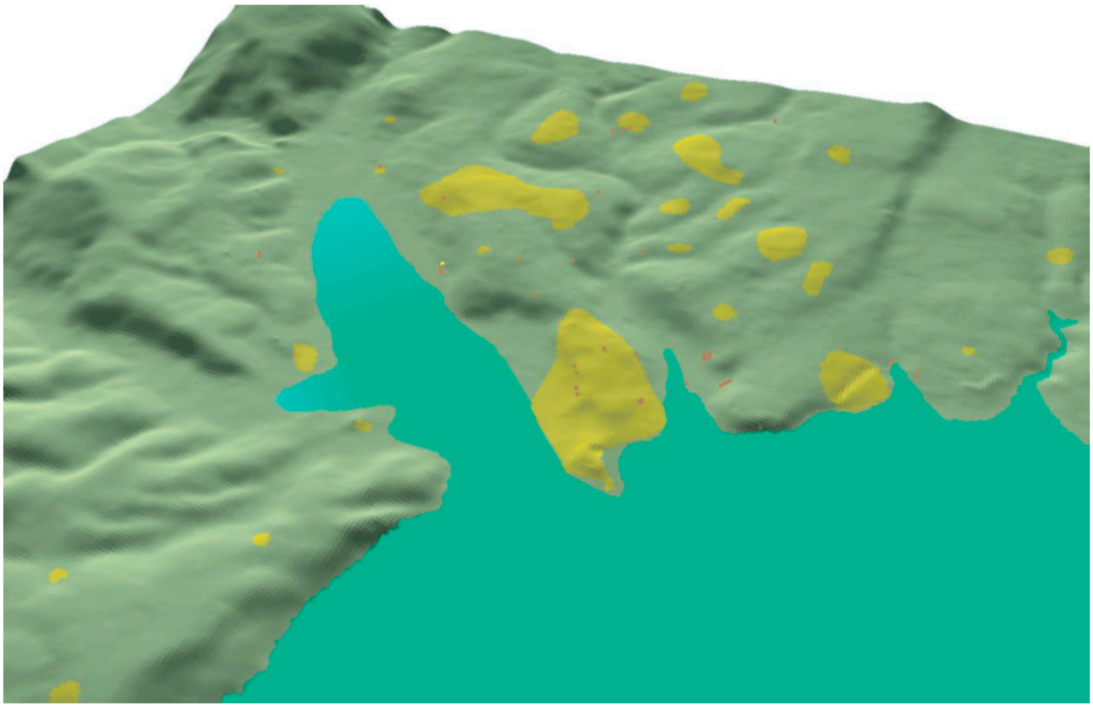

Figure 5. Neopalatial Kastri and environs. Settlement scatters are shown in yellow, definite and possible tombs in brown. A possible contemporary coastline has been reconstructed.

Secondly, beyond the Kastri zone, there are only a very few larger sites and in only one case, are any of these over 1 ha in size. More significantly, even these few slightly bigger scatters that do exist do not appear to be located in ways that suggest they were second-order centres organising smaller parts of the countryside. On the contrary, several (e.g. 083 and 121, Fig. 2) are located in areas that are both relatively isolated from other sites and apparently marginal in terms of their agricultural productivity. Rather than see these as 'more important' within a theoretical Kytheran socio-economic (or political) hierarchy, we could regard them as the product of the different economic or social priorities of their inhabitants (which affected where such sites were located and how they developed internally). A greater involvement in animal husbandry and/or a preference for limited household nucleation rather than dispersal (see below) are conceivable explanations.

Leaving these possible anomalies aside, the vast majority of the Neopalatial scatters are between 0.1 and 0.3 ha in extent. For several reasons, these probably represent small, one- or two-family farms. Firstly, many intensive surveys in Greece in the last few decades have identified very large numbers of such small scatters and, while the degree of *permanent*, year-round residence involved remains difficult to assess, the consensus is that they are often the traces of family dwellings (e.g. Whitelaw 2000: 229-33). This is particularly clear for the Classical period in which survey, excavation and written sources can be used in combination to get quite a nuanced picture of the types of activities involved (Gallant 1991; Lohmann 1992; Jameson 1994; Foxhall 1996; Acheson 1997; Whitelaw 2000; Pettegrew 2001; Raab 2001).

In the second place, there is a range of excavated rural buildings from MMII-LMI Crete that offer convincing contemporary models for what sub-surface structures the Kythera scatters are likely to represent (Figure 6).[2] Although, these have been given different labels and functional identifications by their excavators, it is contended here that many are in fact the houses of nuclear families (perhaps 4-6 individuals on average) involved in agro-pastoral subsistence of some kind. Indeed, they share notable similarities in overall size, layout and material assemblage. All involve one main rectangular building of 80-140 sq m, with a large room off the main entrance and several smaller adjoining ones (this floor area and degree of sub-division are similar to 'average'-sized houses in Neopalatial towns, especially at Gournia [Whitelaw 2001: figs. 2.2-2.5]). Where adequate information is available, they each also possess pottery assemblages of mixed function (tableware, storage vessels and processing equipment) and few if any special finds (slag, votives, weaponry, human bone, large amounts of fineware) to suggest specialised roles other than subsistence.

[2] The main excavated examples referred to here are Chalinomouri (Soles and Davaras 1996: 207-210), Chrysokamino (Betancourt et al. 1999; Floyd 2000), Kato Mesara Stou Kouse (Marinatos 1924-5), Kontokephalo on Karpathos (Blackman 1998: 108, 1999: 106, fig.131), Rousses Chondrou Viannou (Platon 1959) and several east Cretan sites (Tzedakis et al. 1989; 1990; Chryssoulaki 1999). Also possibly relevant, though close to the urban zone at Mallia, is the LMI house at Agia Varvara (Pelon 1966). Many of the east Cretan buildings have been identified as 'guard-posts' on the basis that they are often inter-visible with their neighbours, located on routes through the landscape and/or (in the case of Cheiromandres: Tzedakis et al. 1990: 44) that the surrounding terrain has been unsuitable to farm in modern times. Rural sites can of course perform a variety of roles on different occasions, relating to shelter, storage, production and defence, and the east Cretan examples may well have been constructed with a defensive role in mind, but there is no evidence that they are 'official' or related to recognisable military or administrative activity in any way.

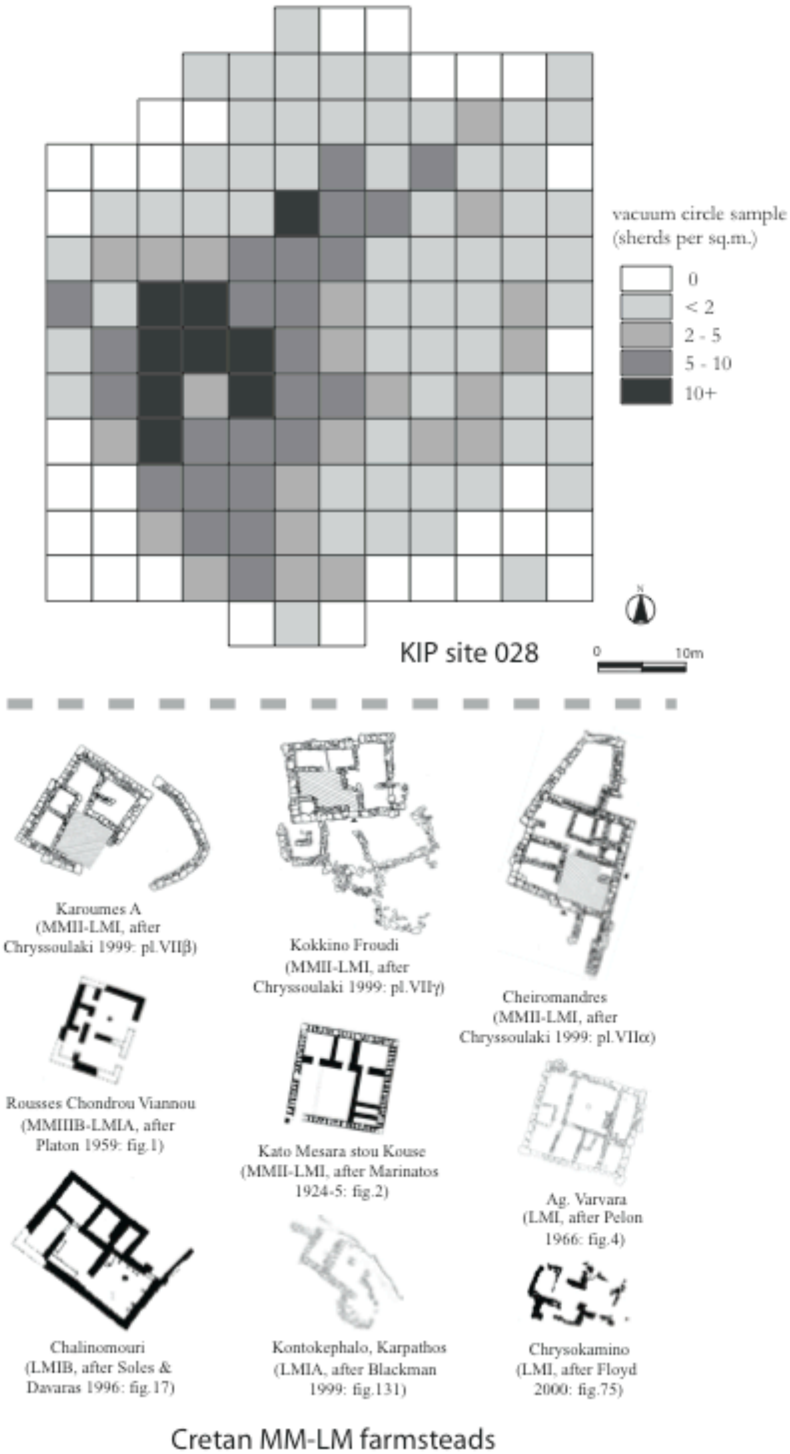

Figure 6. Ceramic density (by vacuum circle) for site 028 and examples of Neopalatial rural buildings on Crete.

Indeed, this is exactly the range of material repeatedly found on the Kytheran sites (C. Broodbank and V. Kiriatzi, personal communication). Gridded collections (vacuum circles and diagnostic grabs) have produced large amounts of ceramic material and these assemblages consistently suggest a full range of household activities, including the storage and processing of agricultural products (pithoi, grinding stones, loomweights), as well as food preparation and consumption (tripod cooking-pots, jugs, cups, a few finewares, e.g. Broodbank

1999: 'site 2'). More precisely, apart from the peak sanctuary at Agios Georgios, there are as yet no signs that the Neopalatial sites can be sub-divided, on the basis of their surface material, into industrial, ritual and/or otherwise functionally-specialised locales. In addition, while we should bear in mind that Greek and Mediterranean environments have been exploited through a greater variety of semi-permanent and contingent rural residence strategies than is often assumed (Whitelaw 1991: 413-18), the functional range and consistency of the material culture found at these sites probably allows us to discount the possibility that they were very temporary shelters or fieldhouses. Likewise, the presence of contemporary rock-cut tombs close to at least some of the rural sites (001A, 028, 083 and others for which the identification of rock-cut features as Neopalatial tombs is less secure) also suggests some degree of residential permanence.

If the excavated Cretan examples are appropriate models for the smaller Kytheran sites, then it is worth noting that, even for fairly well-defined, stable scatters, the extent of surface finds will be much larger than actual roofed dwelling space. This is borne out by the evidence at the habitation site of Chrysokamino on Crete, where surface finds extend over ca. 0.6 ha (and perhaps up to 0.8ha), but excavation has shown that there is only one main building area (representing partially superimposed LMI and LMIIIA phases) of roughly 0.05 ha.[3] This discrepancy undoubtedly reflects the effect of geomorphology and post-depositional processes, but traces of extraneous walls and rock cuttings suggest that in addition, the surface scatter (especially in areas of lower density) also points to the presence of animal pens, refuse dumps, boundary walls, agricultural processing installations and gardens in and around the main habitation. A very schematic model of what might be involved is offered in Figure 7 (drawing partly on results presented in the sections below).

[3] No gridded collection was made at Chrysokamino, but formal attention was paid to surface finds during the Kavousi-Thrypti survey (Haggis 2000) and prior to excavation. At Chalinomouri, a similar pattern was observed in which the actual scatter was larger than the excavated building; here again there was evidence for walls and installations in the surrounding area. My thanks to P. Betancourt, D. Haggis and J. Soles for discussing with me the scatter sizes of these sites and their possible implications.

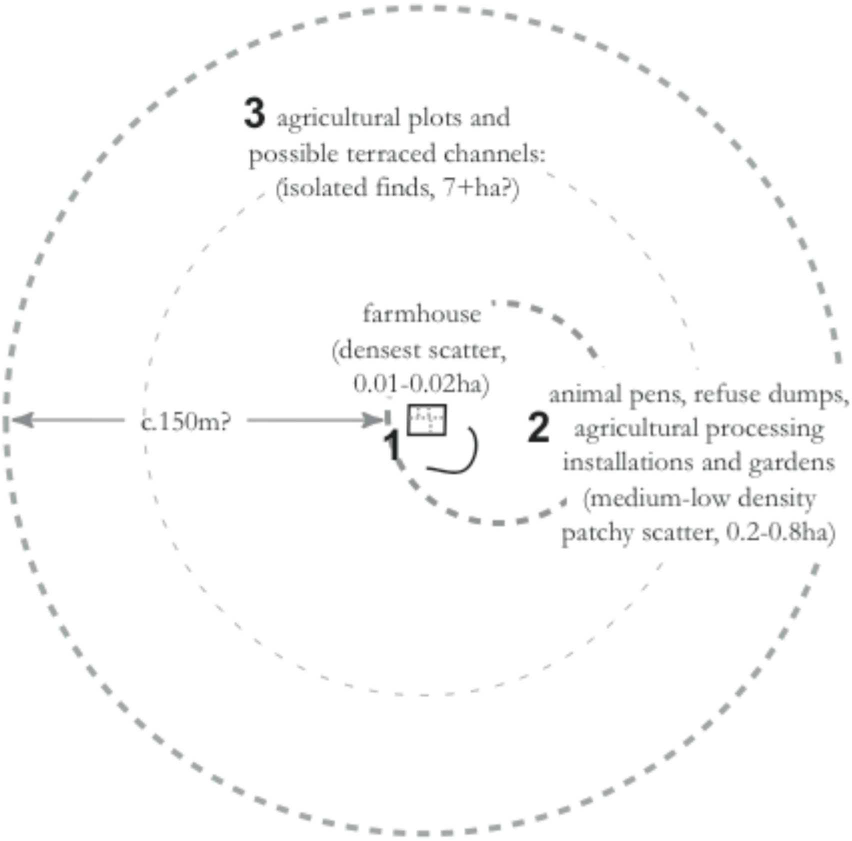

Figure 7. Schematic model of small Neopalatial rural scatters. (N.B. The distances and areal measures are rough suggestions only.)

This picture of scattered family farms on Neopalatial Kythera is in many ways a surprising one. While it has certain similarities to the Classical pattern of rural farmsteads, it contrasts strongly with a) the modern landscape of nucleated villages, and b) the more developed, multi-tiered settlement hierarchy in much of contemporary Neopalatial Crete (for a regional summary, see Driessen 2001). The preceding Protopalatial landscape beyond Kastri seems to have been a relatively empty one. Likewise, the succeeding period sees the disappearance of all but a few of the Neopalatial rural sites and the founding of very few, if any, new ones. In other words, the Neopalatial period on Kythera was diachronically speaking a brief pulse of settlement activity and an example of pioneer efforts at colonising new terrain. This in itself is a contrast with the situation on Crete where colonisation episodes at the rural household scale usually occur much earlier (and rarely if ever in near-empty landscapes) in the Pre- or Protopalatial periods (third to early second millennium BC), to be followed thereafter by greater nucleation and status differentiation (e.g. Haggis 1996; Driessen 2001). The fact that the network of dispersed settlements was relatively short-lived on Kythera may in part explain its lack of hierarchy: a more developed multi-layered system did not have enough time to develop. Moreover, what is crucial to note is the absence of any monumental rural residences, equivalent to the Cretan Neopalatial villas, which might signal a resident rural elite. Indeed, if we look for political elites in such a landscape, we would have to suggest that they were concentrated at Kastri, from which comes the vast majority of our evidence for prestige goods and multi-chamber tombs. Such privileged groups may conceivably have directly or indirectly extracted a surplus from the rural sites, but they may also have drawn some of their wealth from trade and/or the exploitation of the fertile immediate hinterland of Kastri (the Palaioplis and Vothonas valleys) where few discrete Neopalatial scatters have so far been found. (This absence, however, may also partly be the result of poor archaeological preservation due to intensive Classical activity in the area, and the heavy dissection and disturbance of these valley systems by winter season floods.)

3. Settlement Dispersal

The discussion above hints at the fact that, despite the relatively short chronological period involved, the Neopalatial settlement pattern was not a static one. In fact, we should see it as dynamic at several scales: as we have seen, it reflects a probable demographic build-up from a limited number of Protopalatial sites to perhaps a few more in MMIII, and eventually to a rash of LMI farms. The ultimate source of these extra people is unclear: perhaps they were the product of demographic build-up at Kastri itself and/or were from an off-island source, but on a human level, the resulting rural pattern also reflects countless individual decisions involving abandonment, expansion, site location and land use. We can think of families and sites as having life-cycles (e.g. Gallant 1991; Goodman 1999) and at certain points in these cycles it may be necessary for some or all family members to colonise new ground and/or build a new house. There are many factors that might prompt this type of decision: for example, the degradation of existing holdings or the requirements of inheritance or marriage arrangements.

One way to identify the smaller scale dynamics is by examining the distance from the edge of any given scatter to its nearest neighbour.[4] When these distances are calculated for each of the Neopalatial scatters (Figure 8), there are a large number that fall within a 200-300 m range. The nature of the overall surveyed sample has a strong effect on the upper tail of this distribution, with a number of sites found on the edges of isolated survey tracts, and hence with very little chance for the discovery of their immediate neighbours.

[4] For what follows, linear distance calculations have been preferred. More terrain-sensitive measures have been explored using the Kytheran data and might conceivably have been used here, but such modelling introduces many methodological complications (especially if routes are anisotropic; for an overview, see Wheatley and Gillings 2002: 151-63). In human terms, the differences between linear and cost-sensitive routes are minimal at the smaller scales often involved.

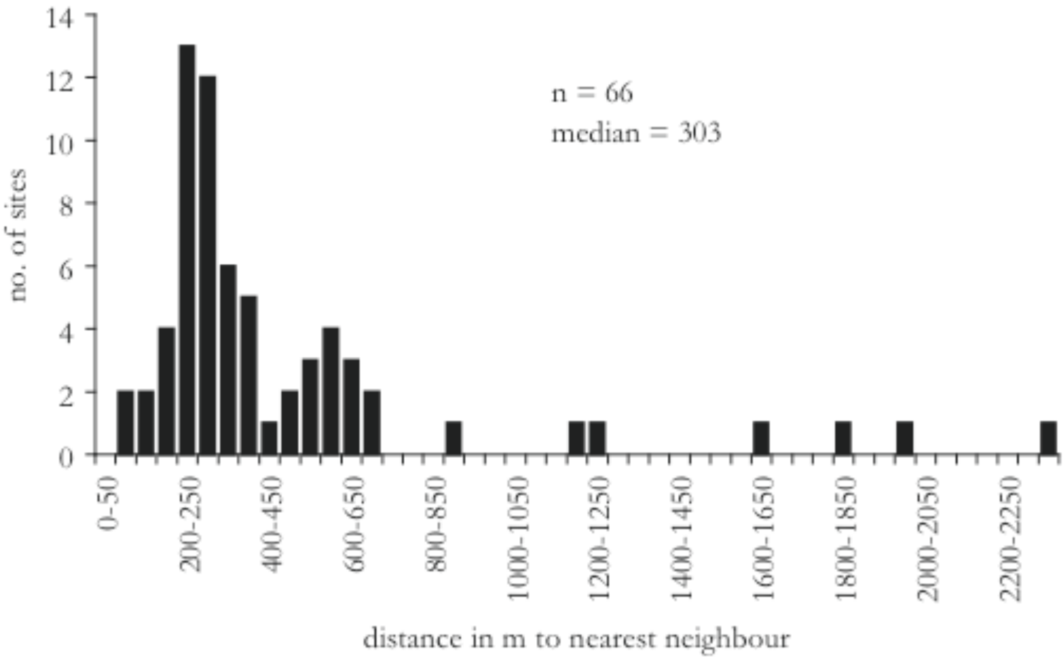

Figure 8. Neopalatial scatters and distance to nearest neighbour.

3.1 Point Pattern Analysis

Another way to look at the same pattern is by calculating the nearest neighbour of the *centre* of each scatter (for recent Aegean applications of such measures: Whitelaw 2000: 239-42; Perlès 2001: 132-47). This is particularly justifiable given the consistent size of the rural sites and has advantages not least because there are a range of existing spatial techniques specifically designed for analysing point data (e.g. Hodder and Orton 1976: 30-97; Bailey and Gatrell 1995: 75-139). Plotting the nearest-neighbour distances of the site centres (excluding Kastri), we get, as expected, a very similar distribution (Figure 9) to the site polygons (scatters), adjusting for the absence of the scatter size itself from the equation. The main question that must be asked is how much this distribution relates to actual human agency and how much is it simply a reflection of the way this number of sites *randomly* distribute themselves within this sampled space (the intensive survey tracts). Is it merely *random*, or does it mean something more, reflecting a *deliberate* spacing of contemporary habitations?

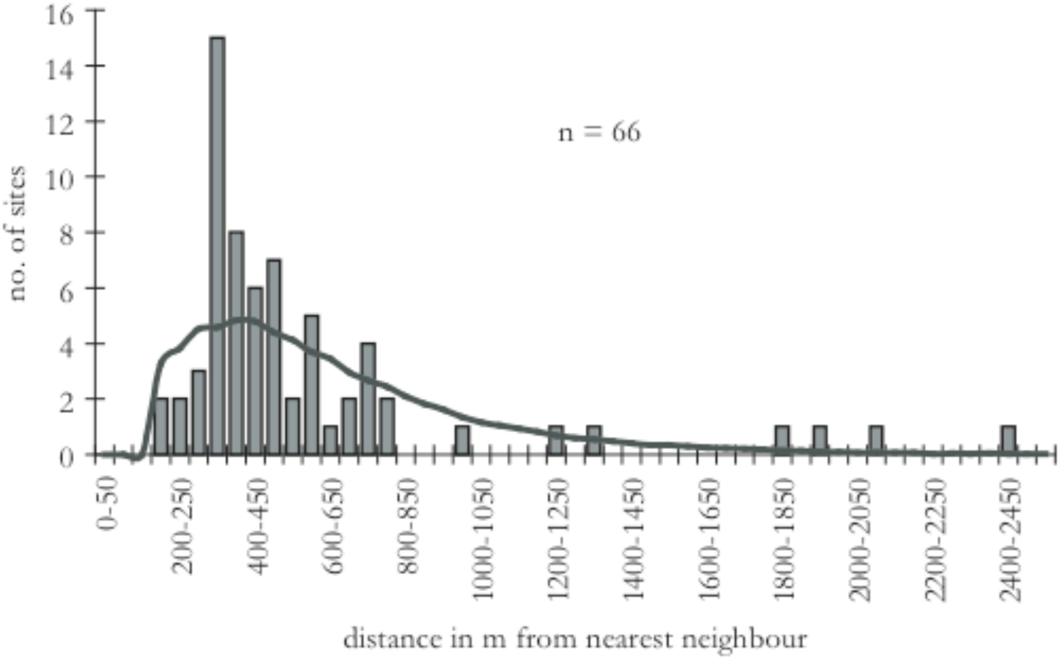

Figure 9. Neopalatial scatter centres and distance to nearest neighbour. (N.B. Only sites within the tract-walked area and beyond the Kastri zone have been included.) The black line represents the distribution of nearest neighbour distances where an equivalent number of points (n=66) are located completely randomly within the intensively surveyed area (based on the averaged results of 1,000 random sets). A Kolmogorov-Smirnov one-sample test suggests that the difference is significant at $p < 0.001$.

Several tests can be applied to point patterns to measure the degree to which they are a) randomly-distributed, b) more clustered together than might be expected, or c) more uniformly-spaced (e.g. Clarke and Evans 1954). However, one of the problems with such point-based approaches is that they are extremely prone to 'edge effects' provided by the boundaries of the sampled dataset. In one respect, therefore, as we saw with the site polygons, intensive survey tracts represent something of a worst-case scenario, with very irregular units of coverage (produced by a desire to sample different landscapes and by accessibility) that threaten to render meaningless any normal calculation of uniformity or clustering. However, treated appropriately, this apparent difficulty is in fact beneficial, forcing us not only to confront the issue of edge effects head-on, but also to recognise that few archaeological landscapes can really be treated as contiguous and continuously-sampled populations. In other words, the presence of undeniably irregular landscape coverage compels us to be completely transparent about what the resulting point patterns represent: in contrast, analyses that make use of site patterns derived from anything less that intensively-explored units (e.g. those from extensive survey or chance finds) are likely to be the result of different levels of investigation in different places and therefore may well produce very biased measures of spatial distribution.

So having noted that intensive survey samples come with as many strengths as weaknesses, how can we grapple with the resulting point patterns? The most useful approach is to generate a set of exactly the same number of points as the Neopalatial site dataset (n = 66, excluding the Kastri zone), but to locate them completely at random *exclusively within the intensively surveyed area* (i.e. the tracts, excluding those in the Kastri zone).

We can then explore the difference between the neighbour distances of this random set and the observed pattern. To make the comparison a reliable and robust one, neighbour distances are calculated for 1,000 independent random sets and an average taken of the results. Moreover, we introduce a constraint stipulating that random points must be a minimum distance apart (here set at 100 m): this is necessary because the real site centres represent surface scatters that are never likely to be closer together than a certain threshold (otherwise they would probably not have been distinguished as independent scatters in the first place). Given these stipulations, the average of the random point sets provides a distribution of *expected* nearest neighbour distances (the solid black line in Figure 9), reflecting the full spatial idiosyncrasies (e.g. the effect of the small unsurveyed 'holes' or far-flung tracts) of the tracted area. This confirms that the observed divergence between expected and observed patterns, first noted for the scatter polygons, is a significant one (at $p < 0.001$).

So we can return to real nearest-neighbour distances and suggest that the high frequency of sites whose nearest, apparently contemporary, neighbour was ca. 200-300 m away is a deliberate Neopalatial strategy. In terms of the human process behind this pattern, we are left with a choice between two models (Figure 10): either 1) gradual infilling of certain landscapes from the outside, or 2) a single founder settlement in a landscape followed by a localised 'budding-off' process. As we have seen, there is some suggestion that, under conditions of overall population growth, we might indeed expect budding-off to occur at critical moments in the life-cycle of a family (e.g. because of marriage and/or inheritance), but existing evidence does not allow us to come to a firm conclusion about whether it is just one or both of the above processes which was at work. (Hodder and Orton [1976: 85-97] have explored some of the statistical problems involved in distinguishing between these processes as causative factors in point patterning; the nature of intensively surveyed samples precludes applying even those problematic techniques that have been suggested.)

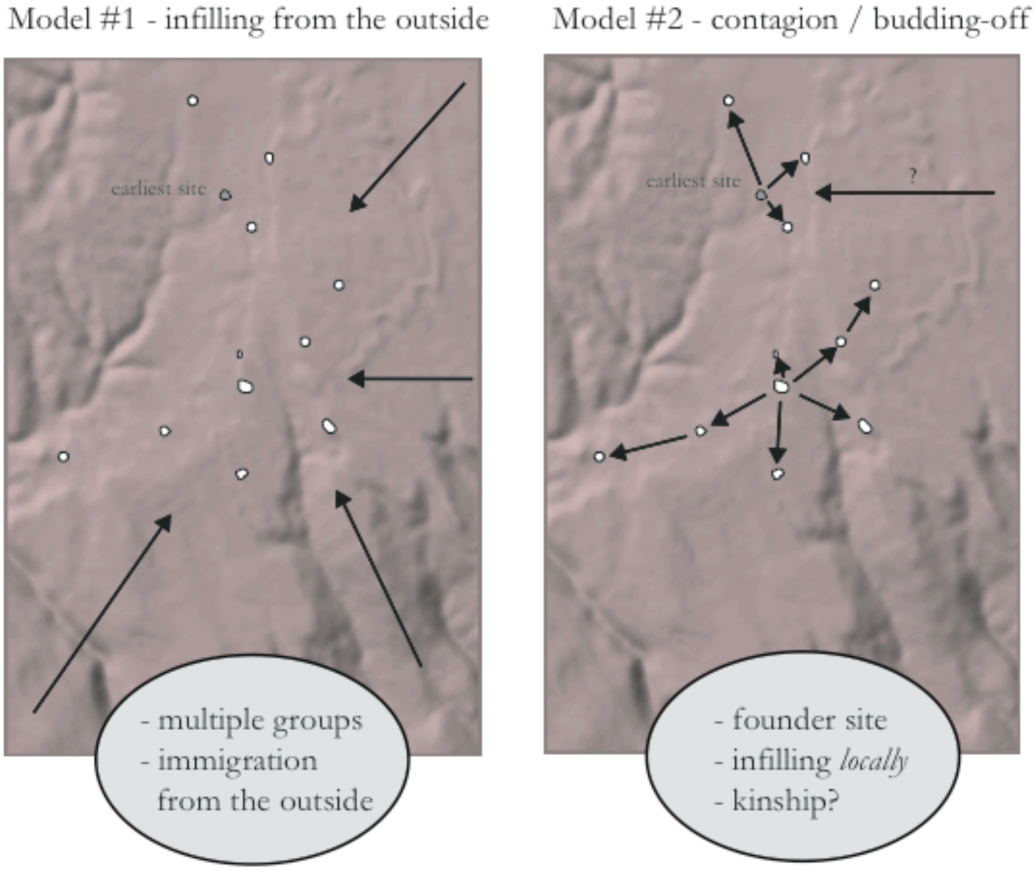

Figure 10. Alternative models of landscape colonisation.

3.2 Site Spacing and Ceramic Distributions

We can explore the spatial structure of these farmsteads further, not just by analysing the core scatters of ceramics documented by gridded collection, but also by looking at the much less dense material beyond them. KIP sought to record total counts of observed ceramics (of any period) for each tract in all parts of the intensively-surveyed landscape and this provides us with a chronologically-undifferentiated map of surface artefacts within the tracted area. In addition, all morphologically diagnostic sherds were collected for subsequent study and dating. Comparing these data-sets allows us to get a fairly nuanced picture of the distribution of Neopalatial finds.

First, we can take five examples of *single-period* Neopalatial sites and consider the 'fall-off' curves (Figure 11) of average observed ceramics (chronologically-undifferentiated densities per tract) as we move away from site centre assuming that much of the counted material in the vicinity will indeed be contemporary; this was done by first interpolating a ceramic density surface (50 m grid) from the tract counts (see Bevan and Conolly n.d. for details). Although there is some variety, the curves suggest that there is a relatively smooth exponential decrease in ceramic density with distance, reaching a minimum at about ca. 200-300 m away (and often then picking up again as we encounter neighbouring scatters). So even at the relatively crude level of the overall tract, ceramic fall-off suggests that we move out from an area of core scatter to reach a real threshold of activity within a radius of 200-300 m.

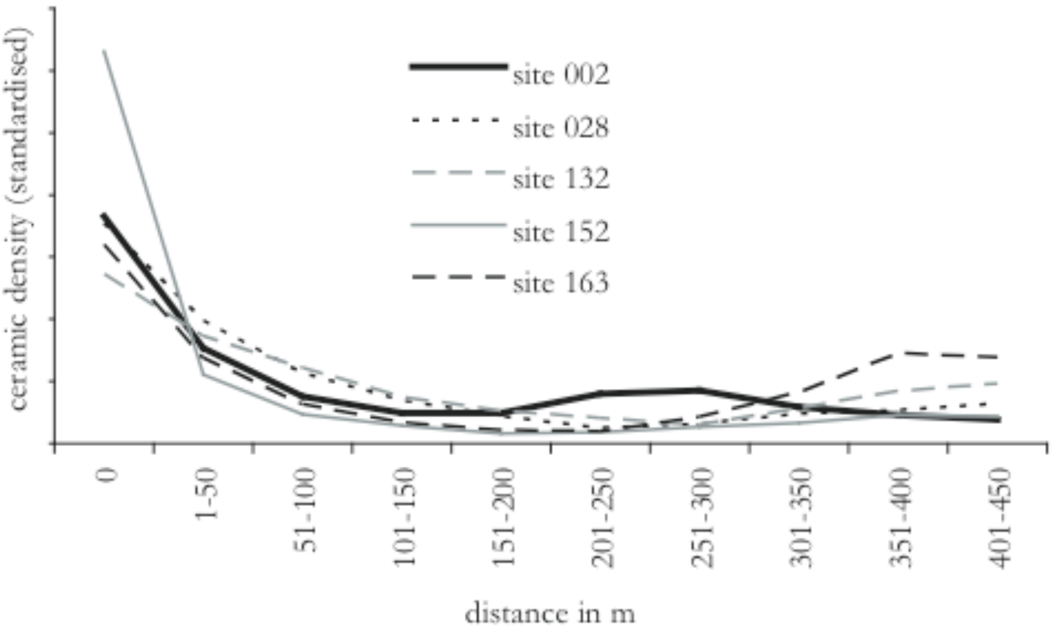

Figure 11. Tract ceramic density (standardised) as distance from scatter centre.

Second, we can look more specifically at the diagnostic Neopalatial ceramics collected during tract-walking. Ceramic analysis is still on-going and so far has only been completed for a limited portion (1,425 tracts covering ca. 700 ha) of the survey area, near the modern village of Mitata. Nevertheless, this sample confirms the impression suggested by the total ceramic fall-off curves. When plotted in relation to the distance from the centre of the nearest contemporary scatter (Figure 12), the vast majority of diagnostic Neopalatial pottery appears to come from recognisable sites or their immediate vicinity (within 100-250 m).[5] Moreover, those few sherds that do not conform to this patten, often come from the valley below Mitata, an area of particularly heavy geomorphological disturbance (e.g. repeated fluvial dissection) which may have destroyed all but the smallest vestiges of site activity. In other words, there is remarkably little evidence at all for *truly* 'off-site' ceramic deposition. Indeed, prior to full-ceramic analysis, but based on tract-walking, site collection and the re-visitation of isolated findpots by KIP survey teams, this appears to hold true for the Neopalatial in much of the rest of the tracted area as well. This paucity of off-site evidence contrasts with other periods on Kythera (notably the Classical to present-day) and, as we shall see, may well relate to the existence of different agricultural strategies. In any case, it is worth emphasising that the Kytheran Neopalatial landscape is most emphatically not a 'hidden' one of frequently buried sites and a clearly continuous cover of cultural material (cf. Bintliff *et al.* 1999). Rather, Neopalatial 'sites' and their immediate environs are highly-recognisable and relatively discrete phenomena.

[5] Diagnostic finds were recorded by walker (each spaced at 15-m intervals), per 100 m or less and, for the distance calculations made here, were then arbitrarily assigned to the mid-point of the walker's line.

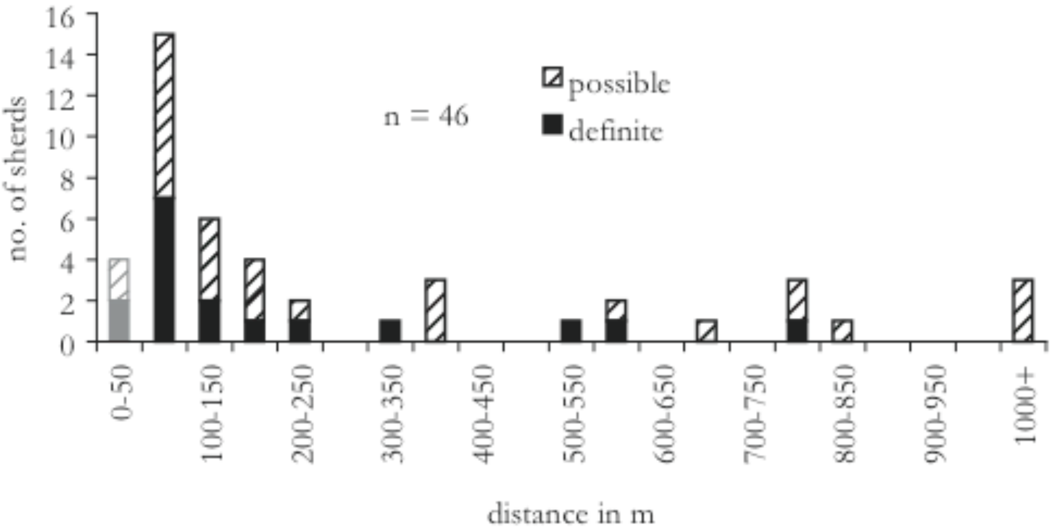

Figure 12. Diagnostic Neopalatial pottery collected during tract-walking and distance to nearest Neopalatial scatter centre (Mitata area). (N.B. Low counts in the 0-50 m category reflect the fact that, during tract-walking, diagnostics were not usually collected from the main site scatter itself to avoid prejudicing subsequent gridded collection.)

3.3. Site Catchments and their Implications

The most obvious explanation for the inter-site distances and ceramic distributions noted above is that they reflect each site's exploitation of a specific catchment of surrounding land. This is especially valid, because unlike the modern Greek pattern of nucleated rural villages in which family land holdings are often highly fragmented, we can probably expect the parcels of land exploited by *dispersed* farmsteads to be more contiguous and closely-grouped around the farm building (Forbes 2000: 208-209). If we think of the observed 200-300 m spacing in terms of area, it would provide each site with an individual catchment of ca. 3-7 ha, which is very crudely the size of holding that might be expected for a one- or two-family arable farm (Halstead 1987: 81-85; Whitelaw 1994: 174, with refs.). In this sense, site spacing (and indeed the fall-off in ceramic densities) may corroborate the evidence of site size — that these ubiquitous, small rural scatters are indeed a household-scale phenomenon. This typical farm size probably reflects the amount of land needed to grow sufficient quantities of cereal crops (usually wheat and/or barley) and perhaps some pulses (see below), but there is also a range of other activities that might be incorporated into what was deemed to be an appropriate set of family holdings. For example, such farms may have grazed limited numbers of livestock (perhaps a couple of sheep and goat, but also pigs or a donkey) and would also have done so in the immediate vicinity of the farm itself (Halstead 1996: 23-24). Modern analysis suggests that one or two sheep or goats could be supported by a hectare of average grazing-land (Le Houerou 1977: 259, table iii; Koster and Forbes 2000: 266). Likewise, we might think in terms of another hectare of scrubland used each year as a source of fuel for heating and cooking (Rackham 1983: 326; Forbes 1997; Koster and Forbes 2000: 268).

However, we should be cautious. With respect to the amount of land given over to cereal production, this generic size of family holding is mostly derived from modern examples of family farms where relatively extensive regimes of plough-driven, arable farming predominate (Halstead 1987). But this is not necessarily the regime that was prevalent in Neopalatial Crete and Kythera. Our present understanding of Bronze Age Aegean farming is very poor (e.g. Hansen 1988) and the limited evidence that does exist often comes from palatial centres where we might expect such regimes to be very different anyway (Halstead 1992; 1999), in terms of underlying consumer demands (e.g. the likely differences in diet associated with varying social status: Smith 2000), economies of scale (e.g. the ability to exploit, sustain and replace traction animals) and overall objectives (e.g. to produce large cash-crops). Concrete examples include the apparent discrepancy between probable specialisation by the palaces in certain cereal crops and wool flocks suggested by the Linear B texts on the one hand, and on the other, bioarchaeological evidence which points to a more balanced, diversified crop regime of wheat, barley and pulses (lentil, chickpea, pea, bean, vetch) and a generalised 'meat' strategy underpinning the management of Bronze Age livestock (Halstead 1992: 108-109; 2000: 115-17; see also Sarpaki 1992; Riley 1999). The probable emphasis on mixed cereal and legume crops is particularly important. A similar picture is suggested by the weeds found in the food caches at Late Bronze Age Assiros (suggesting small-scale, intensive mixed crop husbandry) and has been proposed as a suitable description of household subsistence as early as the Neolithic (Halstead 2000: 115-17). Likewise, it is interesting that wheat and pulses were apparently stored together in room 5 of the small rural house at Agia Varvara, near Mallia in Crete (Pelon 1966: 563-64). This building provides a possible parallel for the type of habitation the smaller Kythera scatters might represent (see above). Intensive farming may also be suggested by the possible chemical evidence for manuring identified in a terrace fill on the island of Pseira (Bull *et al.* 1999).

Based on this admittedly patchy evidence, therefore, we might offer an alternative subsistence model for LM I Kythera that sees dispersed rural households involved in very intensive, manually-worked, mixed or rotated cropping of cereals and pulses. In this strategy, hydrology, construed broadly, would have been an important factor (e.g. Sherratt 1980). One possible reason for the particular density of settlement on the Mitata plateau (Fig. 2) may have been due to copious amounts of fresh drinking water available from several springs in the general vicinity (Pagounis and Gertsos 1984). Far more important, perhaps, was the control of soil moisture. In this regard, it is significant that the aggregate impression formed by geoarchaeological study of the landscape in and around Mitata is that small drainages adjacent to known sites were probably being terraced (across the channel) to retain both valuable Quaternary soils and moisture.[6] Further evidence comes from a road section in the Palaiopolis valley where there are superimposed MM and LM soil horizons apparently accumulated behind or around a cross-channel terrace of this kind (Frederick *et al.* 2003). Similar terracing has also occasionally been noted in other Aegean

[6] The pervading Bronze Age Aegean climate appears to have been slightly wetter and colder that the current one. Moody (2000: 58-59) summarises evidence for a possible 'Little Ice Age' in the second millennium BC and points out that new subsistence practices and water/soil retention strategies (including channel terraces) may have been responses to the invitations of this environmental regime.

Bronze Age contexts (e.g. Betancourt and Hope Simpson 1992; van Andel *et al.* 1997: 48). More generally, such terraced shallow channels are a well-known agricultural strategy in the Mediterranean (e.g. Evenari *et al.* 1971: 97-99; Wagstaff 1992, with refs.; Grove and Rackham 2001: 266-67, fig.14.24) and would have provided ideal locations for horticulture or small-scale arable farming (Frederick and Krahtopoulou 2000: 84).

If this model is correct, then a family might subsist on much smaller plots. A few ethnographic examples suggest in fact that as little as 1-2 ha of intensively-farmed land might be adequate (e.g. Halstead 1987: 84; Hodkinson 1988: 39). We can get a very rough idea of whether the suggested site catchments are still viable under this more intensive agricultural model by looking at the area of channels (the theoretical, intensively-farmed plots) generally falling within such catchments. First, we draw a buffer of 150 m radius (a distance suggested from the observed inter-site spacing) around each of the Neopalatial sites (Figure 13). Sometimes, around Mitata and Palaiopolis, these buffers overlap, but it is interesting to note in passing (though unnecessary to the basic argument) that where this occurs, buffers can be moved in a relatively systematic way with reference to the set of Thiessen polygons produced for the same set of points. When this alteration is made, the resulting buffers fit even more tightly into clustered adjacent groups. Identifying channels is not only a scale-dependent process in terms of extracting this information from a Digital Elevation Model (hereafter DEM), but also with respect to what proportion of the concave surfaces of a given landscape to include.[7] In order to make this analysis as robust as possible, deeper channels were identified a) on their own and b) with their adjacent broader regions of concave surface, essentially bracketing the two most extreme possibilities of what we might consider drainage channels (Fig. 13). The areal extent of both a) and b) *within* the buffered site catchments was then measured (Figure 14). The calculations are relatively coarse, but both a) and b) suggest that the vast majority of sites would indeed have immediate access to between 1 and 4 ha of shallower channel, an area sufficient to sustain a single family by more intensive farming techniques.

[7] Channels were delineated in Landserf with reference to cross-sectional curvature. Morphometric definitions of this kind are scale-dependent: in this instance curvature was calculated within a ca. 100 x 100 m neighbourhood, because this scale seemed to give priority to the general size of channel found to be most directly associated with Neopalatial sites by georchaeological investigation in the field.

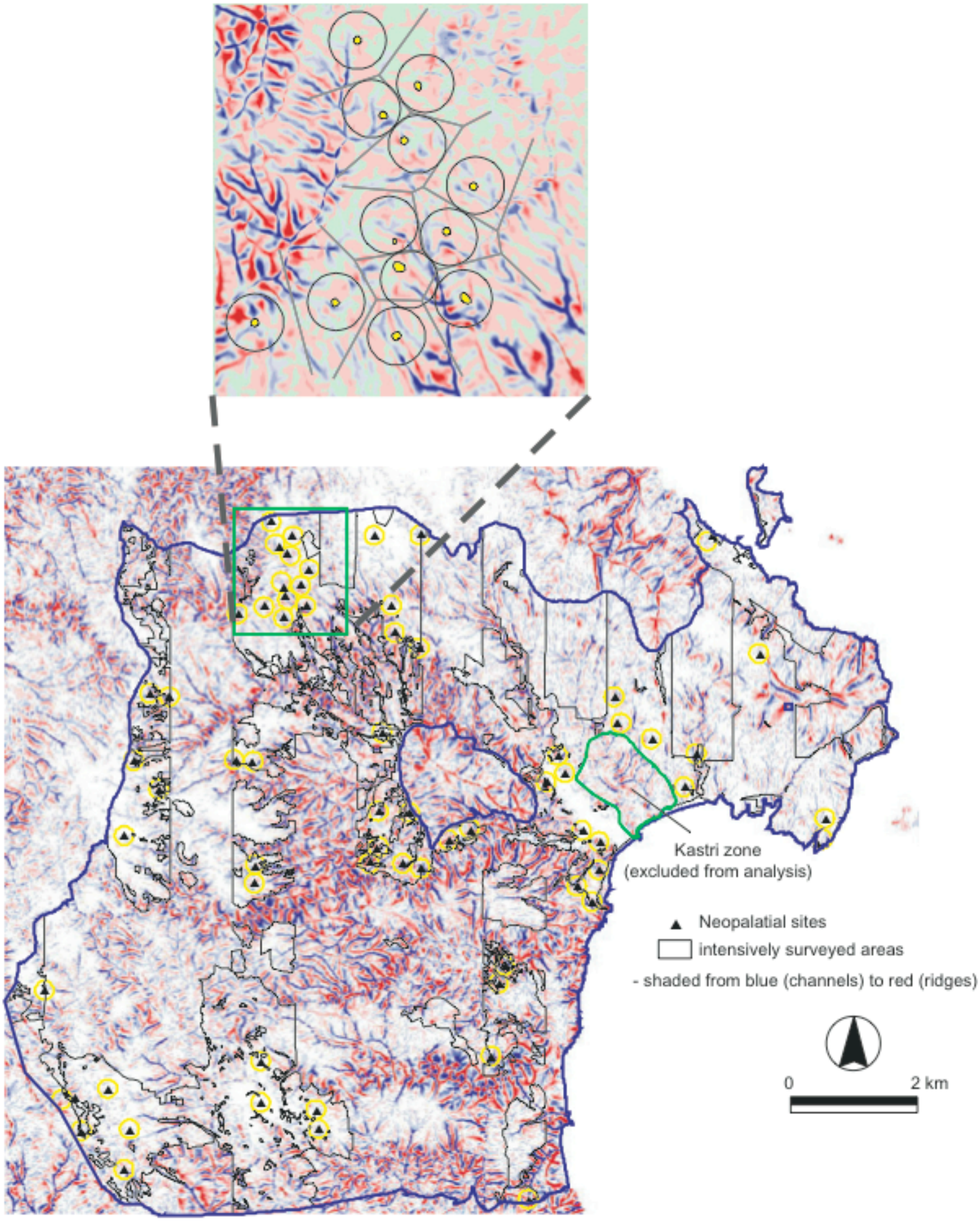

Figure 13. Site catchments and channels (in blue; convex surfaces in red).

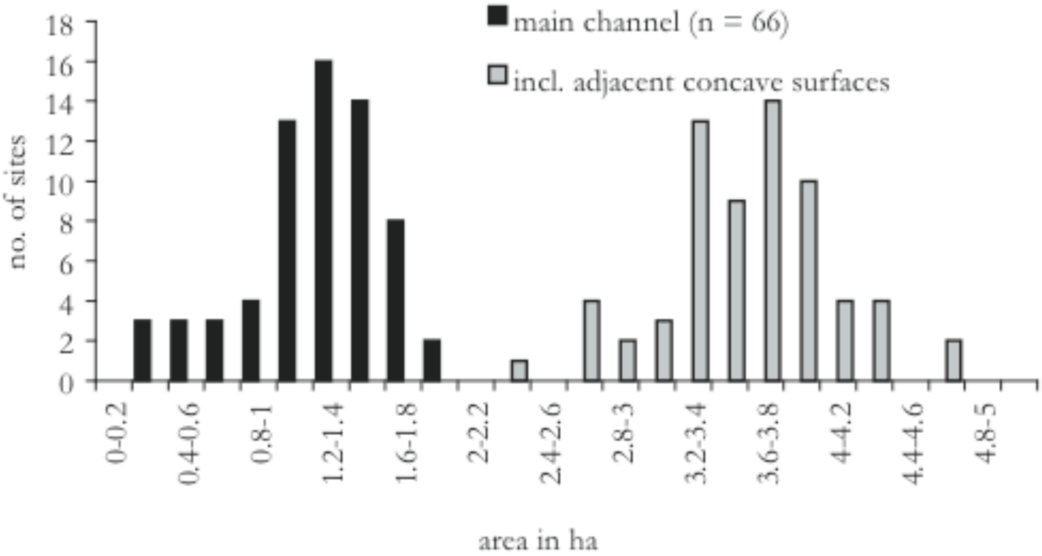

Figure 14. Area of channels within 150 m radius.

Thus the observed site spacing would in theory be consistent with either extensive or intensive farming strategies. It is probably unlikely that both were in operation at the same time, but of course, cross-culturally, there exists a more graded range of intensification/extensification choices than the dichotomy implies. Whatever their general preference and within certain limits, Neopalatial farmers on Kythera are likely to have exhibited some flexibility in this regard, in different areas of the island, at different times in the life-cycle of the family and when confronted with particular, unforeseen challenges. Worth noting in passing is how dispersed settlement and possible intensive horticultural practices might relate to the management of subsistence risk. In the 19th-20th century Greek countryside, the dominant settlement and land-use patterns have been those of nucleated villages and extensive cereal agriculture. Holdings have often been highly fragmented, reflecting not only the legacy of existing patterns of marriage and inheritance, but also a means of spreading subsistence risk by the exploitation of a variety of different micro-ecologies (i.e. relating to the spatially heterogeneous impact of climate and pests, even at very small scales: Halstead and Jones 1997: 284; Adams 2000; Forbes 2000). In contrast, settlement dispersal and likely intensive farming probably implies, as we have seen, that on Neopalatial Kythera holdings were smaller and more closely packed around the farm building. In this environment, ecological risk is likely to have been managed in different ways (Halstead and O'Shea 1989): a) through diversification (of crops and animals) *within* intensively farmed plots, rather than diversity of growing conditions *between* plots in varying locales, and b) through 'social storage' or cooperation between neighbouring farms (perhaps sometimes facilitated by kinship links).

To summarise the previous and present section, the surface scatters of Neopalatial pottery on Kythera suggest one large urban zone around Kastri and a large number of farmstead-sized units scattered throughout the countryside with little or no clear evidence for second-order organisation of these rural sites. The spacing of the farmsteads is relatively uniform (especially when the nature of the surveyed sample is taken into account), apparently reflecting the organisation of agriculture and other subsistence strategies in and around the farm building and perhaps the budding-off of new sites from old ones at certain points in time. These catchments are compatible in areal terms with either extensive or intensive agricultural regimes, but the most likely model is an intensive one, involving mixed cropping of cereals and pulses, probably within shallow, terraced drainages adjacent to such sites.

4. Locational Modelling

The reason why sites are located where they are in the landscape is a highly multi-scalar phenomenon, both over time and space. For example, we have already seen that new farms were probably located in immediate physical relation to existing ones. Likewise, the Neopalatial landscape would already have been 'enculturated' over time in other ways, with landmarks, special places, myths and traditional configurations. This will undoubtedly also have affected settlement patterns. Furthermore, the initial choice of locale for a site runs together, in interpretive terms, with a range of post-foundation factors governing its survival and continued prosperity. Spatial scales are just as important: for instance, the location of the large port centre at Kastri (or rather its prosperity and size) was in part determined by the demands of off-island connectivity, particularly its position on a route from Crete to the metal sources of Lavrion in Attica and various possible resources in the southern Peloponnese (e.g. Sakellerakis 1996: 88-92). As such, the patterns and processes (long-range maritime links, major geopolitical interactions) influencing why it is where it is in the landscape cannot be simply conflated with those influencing the location of smaller rural sites.. Bearing these issues in mind, the next sections concentrate on the rural sites and explore some basic parameters that might have effected their positioning. The advantages of using a GIS to automate and formalise the correlation of site location with various cultural and environmental variables has been recognised for some years (Warren 1990; Dalla Bona 1994; Petrie *et al.* 1995; Kuna 2000; Wescott and Brandon 2000, with refs.). The following discussion explores these possible environmental parameters and cultural agendas, but does not seek to produce a full predictive model, for several reasons. Firstly, as suggested above, although we can isolate more and less geoarchaeologically-stable environments, locational modelling, particularly based on parameters such as modern topography, must contend with the implications of a dynamic Mediterranean landscape and will need to emphasise and exploit privileged informational 'windows' as much as generalise across full survey datasets. Secondly, as we shall see, Neopalatial farmsteads occupy a relatively wide range of niches in the landscape. Some patterns are visible, but the range of suitable locales remains quite large. Indeed, the inability to exclude large, contiguous swathes of land on the basis of environmental parameters alone is a salutary reminder of how inappropriate it would be to espouse too deterministic an approach to how humans decide where to live, especially in a Mediterranean setting (Horden and Purcell 2000: 53-88), and especially under possible intensive agricultural regimes.

4.1 Background Variables

This section first discusses a range of commonly-used but highly problematic variables in location modelling and offers both qualitative and quantitative assessments of their possible relevance. Two more promising broader perspectives – terrain roughness and hydrology – are then introduced in greater detail. The method used is similar to that followed by Warren and Asch (Warren 1990; Warren and Asch 2000).[8] The amount of landscape characterised by a given variable category (e.g. marl limestone or slopes of 0-2º) and covered by Neopalatial sites can be compared with the total amount of terrain in this category found within the intensively surveyed tracts. These proportions (expressed as the percentage of terrain covered by site scatters, per variable category) allow us to explore the relationships between environmental variables and the location of known sites robustly, and if they are found to be statistically significant (by Chi-squared or Kolmogorov-Smirnov one-sample tests), to subject them to logistic regression.

Slope is a variable that highlights the problems both of modelling method and survey sampling. Neopalatial scatters are usually found on relatively flat land, mostly under 10º and almost always under 15º. Indeed, comparing areas with scatter to the background representation of slope values in the intensively surveyed area confirms that there is a statistically significant preference for areas of flatter gradient. However, when the percentage of terrain covered by site scatters is regressed against slope, the resulting relationship is unclear and not particularly discriminating. This is the case for two main reasons: firstly, KIP survey tracts under-sample steeper slopes (walkers find it hard to survey all of the steeper terrain). Steeper slopes are often surveyed extensively and Neopalatial sites have not been found, but there is no acceptable way of including such information in a quantified model (how would one define what areas were 'covered' and which were not?). Hence parts of scatters found on steeper slopes gain more statistical weight than they perhaps should. Secondly, sites in geomorphologically unstable zones (e.g. with evidence for post-Bronze Age fluvial dissection) sometimes appear on locally steep slopes that may well have been flatter in the past. An indicator of terrain texture and gradient that is more robust than a simple slope analysis is explored below, but all topographic indicators will have to contend with this issue.

Aspect is an environmental variable that conceivably relates to differing exposure to sunlight and prevailing winds. There is no apparent correlation between aspect and site location on Neopalatial Kythera either at the level of the site scatter or if we run a similar analysis on the theoretical catchments around them.

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[8] The DEM used for all of the following analysis has a 10-m resolution and was produced using ArcInfo's TOPOGRID algorithm (Hutchinson 1989; Hutchinson and Dowling 1991) from manually-digitised 4 m (and judgmental 2-m) contours and spot heights, derived from 1:5,000 Greek Army maps. A large number of different interpolation algorithms were explored in the creation of the DEM, but given the nature of the base data, TOPOGRID was found to produce the best results. At this scale, there are no signs of the inter-contour benching sometimes associated with contour-based interpolations.

Bedrock Geology and Soils – The existence of soils suitable for cultivation is almost certain to be important to site location. Indeed, geoarchaeological investigation suggests strongly that Neopalatial sites were located in proximity to lighter soils that could be turned over easily by hand (C. Frederick and N. Krahtopoulou, personal communication) — mostly Quaternary alluvium, found either in pockets within channeled areas (especially on the Neogene marls) or filling a very few larger basins. Except in areas of heavy alluviation, soils are linked to bedrock geology and the intensively-surveyed tracts sampled most of the island's major geological units. Neopalatial sites are found on Neogene marls and conglomerates, various Cretaceous limestones and Eocene flysch. In fact, at this stage, it is not possible to define any statistical correlation or relationship between site location and the mapped bedrock geology of the intensively tract-walked area. This is probably true for several methodological reasons: a) soils and bedrock are correlated, but not identical; b) the existing geological maps (1:15,000 scale) are of mixed accuracy when actually ground-truthed and conclusions from them should remain tentative prior to further field-checks; c) Quaternary alluvium is particularly poorly mapped and is also prone to being eroded away by subsequent fluvial activity, or in specific places (such as Palaiopolis, immediately south of Kastri) later Quaternary build-up obscures Neopalatial scatters; and d) especially given the intensive agricultural model suggested above, in which Neopalatial farmers were probably able to exploit relatively small parcels of soil, there are bound to be exceptions to the overall pattern.

So prior to a more secure geoarchaeological reconstruction, it is misleading to rely too heavily on quantified results. Moreover, one major unit of metamorphic rocks (including gneiss, mica schist, phyllites and marbles) lies outside the tracted area, but covers much of the northern part of the island. This metamorphic landscape typically consists of very broken-up terrain and it is unclear whether we can extrapolate the known settlement pattern to this very different geological zone.

Visibility is another potentially important locational concern. Interaction between farms (whether pedestrian or visual) is suggested by the site-spacing, as we have seen; but, given the very small scales usually involved, it is not informative to consider formally the intervisibility of individual sites. But one particular locale, which could have had some specific cultural significance is the contemporaneous peak sanctuary on Agios Georgios (Sakellerakis 1996), especially since there is some suggestion that visibility between settlement and sanctuary may have been an important aspect of the relationship between these two different types of site (Peatfield 1987). A simple cumulative viewshed was calculated from a range of points around the sanctuary (Figure 15), but it suggests that there is *no* clear relationship between farmstead location and lines of sight with the peak sanctuary; more subtle viewshed parameters considering the directionality of lines of site or their differing quality over different distances (e.g. Wheatley and Gillings 2000) do not produce significant results either. For example, few if any of the cluster of sites on the Mitata plateau are intervisible with Agios Georgios. Indeed, it seemed unlikely from the outset that small-scale agricultural settlements would be predominantly concerned with such a locational strategy, but it is useful to confirm the absence of any obvious pattern. The rural farmsteads definitely do not represent a 'sacred' landscape in this simple sense.

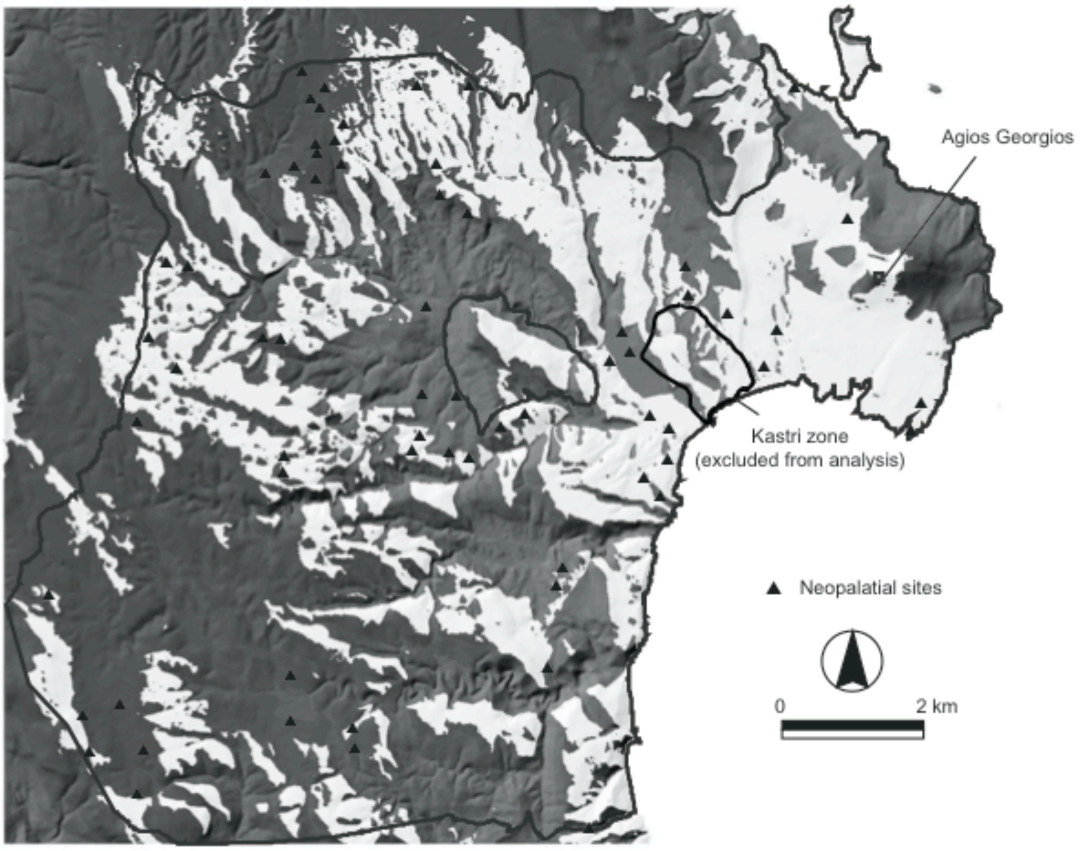

Figure 15. Neopalatial rural sites and intervisibility with the Agios Georgios peak sanctuary (areas intervisible with Agios Georgios are shown in white).

The variables explored above may provide important insights when treated more qualitatively, but their ability to quantify locational patterns for this particular dataset has so far proved limited. Two more promising approaches are explored in greater detail below.

Terrain Ruggedness – Expressions of relief have been used in modelling archaeological site location before and have a long history in landscape ecology and geomorphology (Forman 1995: 304-6; Wood 1996: section 2.2.1, both with references). For example, the ruggedness of local terrain can be a useful indicator of the types of landscape that might have been deemed suitable for small-scale farming and settlement. Typically, relief indices are calculated in a GIS as the range in elevation values found in a specific neighbourhood around a chosen point in the landscape. However, such a measure is quite crude and gives no idea of the shape of the landscape, whether it is broken up by sharp or undulating curves. More importantly, relief is being expressed at a single arbitrary scale and could always be calculated over larger or smaller neighbourhoods, thereby expressing larger or smaller scale relief.

Several alternative, more sensitive measures of terrain ruggedness, such as fractal dimensions (e.g. Mandelbrot 1967; Burrough 1981; Mark and Aronson 1984; Clarke 1986) or positive wavelet analysis (Gallant and Hutchinson 1996) have been proposed, and these emphasise the need to consider variation over different spatial scales. A related approach offered here focuses on multi-scale variation in terrain curvature. Such analysis is not offered as a 'cure-all' for expressing and characterising topographic relief, but is explored below because: a) it is not scale-specific, b) it deals with a variable (curvature) which might be directly relevant to Neopalatial agricultural regimes (conceivably focused on channels), and c) because, amongst a variety of relief measures explored in relation to Neopalatial sites, it produces the clearest results.

Various curvature measures can be derived from a DEM by fitting a quadratic surface to a given cell neighbourhood and analysing two-dimensional slices through it (Wood 1996: 4.2.2). In this case, we specifically consider 'cross-sectional' curvature which is measured directly across channels (concave surfaces with negative curvature values) and ridges (convex surfaces with positive curvature values).[9] The simplest calculation of curvature uses the elevation values of the chosen cell in the DEM and its immediate neighbours (a 3 x 3 matrix), but the same operation can also be performed on any number of adjacent cells. Landforms that express themselves strongly at one neighbourhood scale may not do so at others (Figure 16): for example, they might be clearly identifiable channels at small-scales (e.g. 3 x 3 cells), but appear relatively flat or as part of wider ridge systems when seen at larger ones (e.g. 45 x 45 cells).

[9] More precisely, it is calculated for the plane formed by the slope normal and perpendicular aspect. The following analysis was conducted in Landserf; my thanks to Jo Wood for discussing aspects of his program and the possible relevance of multi-scale analysis.

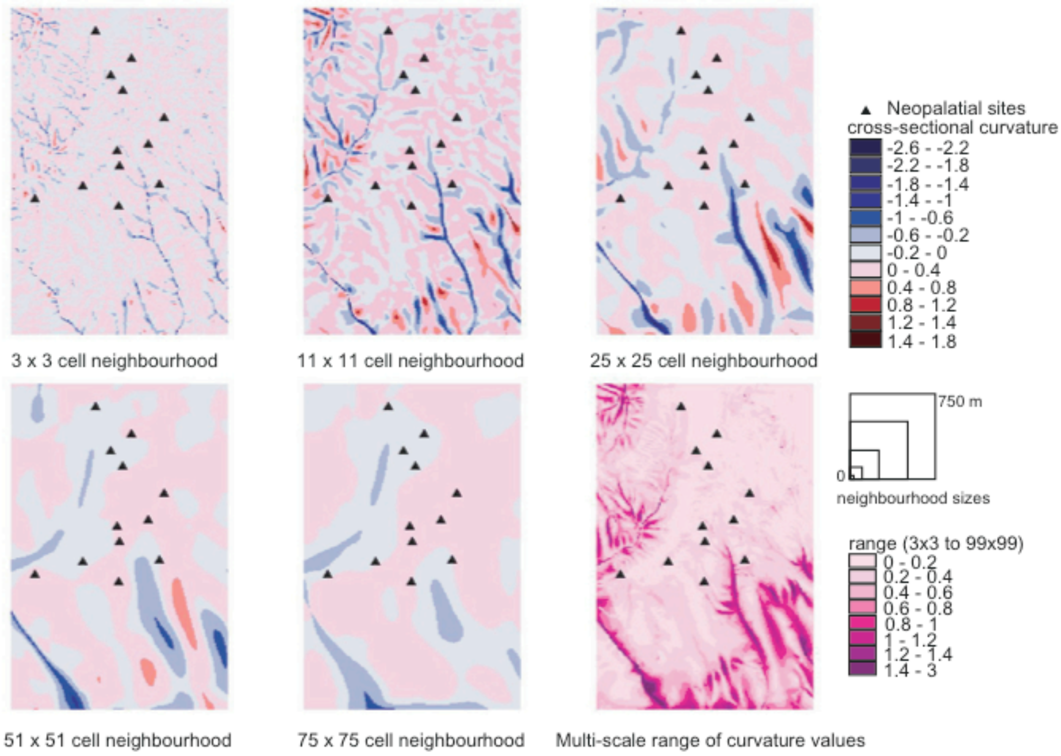

Figure 16. The effect of scale on terrain curvature (Mitata area).

Terrain ruggedness is therefore better expressed as a function of the *dispersion* of the curvature for a given cell as it is measured across a range of scales. The simplest (non-parametric) measure of this dispersion is the range and this was calculated for the Kythera survey area at all neighbourhoods from 3 x 3 cells (ca.1 ha) to 99 x 99 cells (ca.100 ha; Figure 17). Regression suggests a strong linear relationship in which Neopalatial sites are located in areas of low-medium multi-scale range in curvature, or put more simply, in areas that are of persistently low-medium relief (Figure 18).

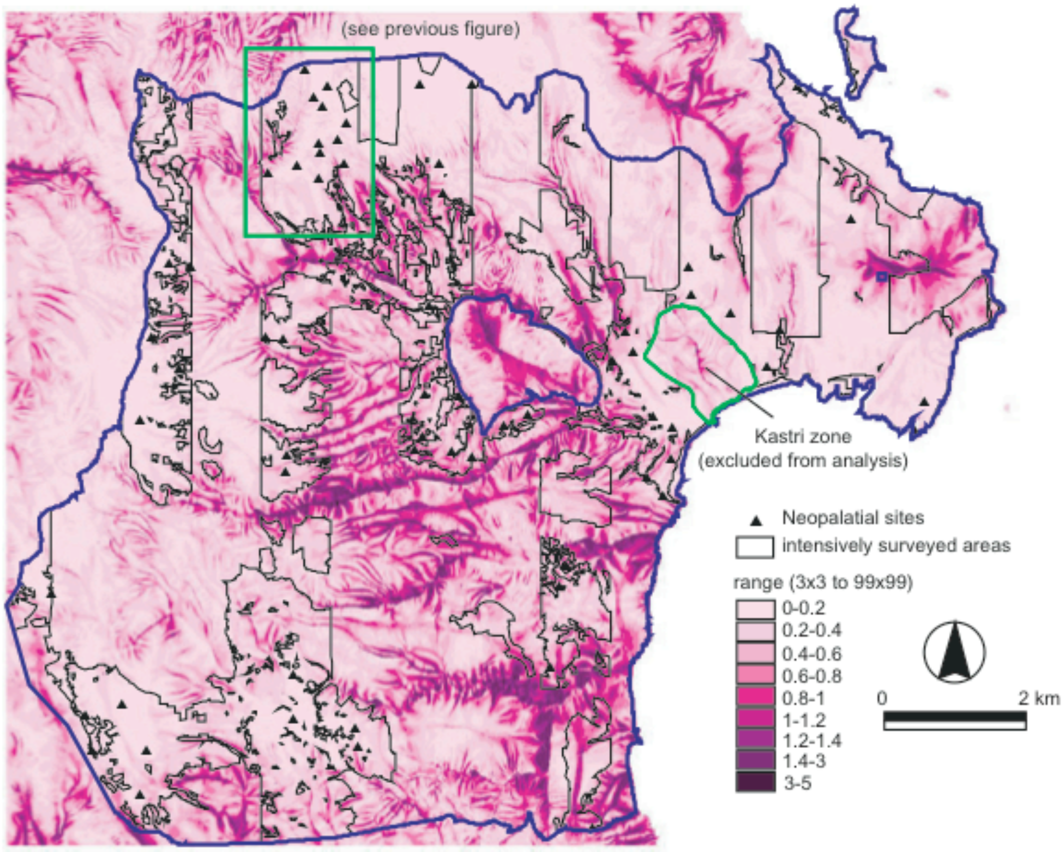

Figure 17. Neopalatial rural sites and multi-scale range in terrain curvature.

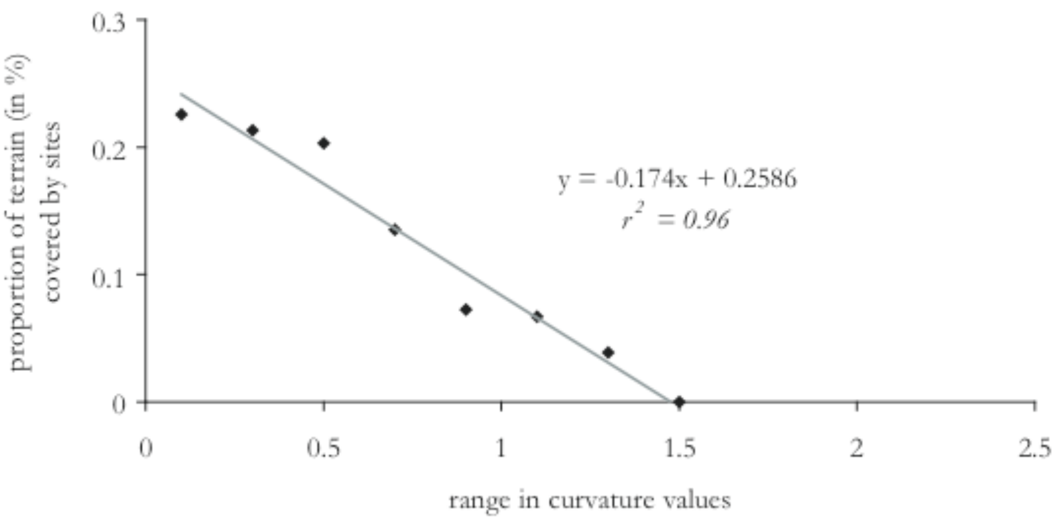

Figure 18. 1. Correlation between Neopalatial sites in the KIP tract-walked area and multi-scale range in cross-sectional curvature.

This kind of measure captures accurately the fact that the rural sites are usually not found on steeper slopes or the flatter sections of ridge and channel in-between. However, despite being an index derived from multi-scale analysis, it remains 'regional' in a sense, because it defines broad types of terrain rather than exact locales. Indeed, it is also only moderately discriminating – there are many areas on the island that qualify as terrain that might have sites – but, as we shall see, is nonetheless useful for investing demographic models with greater sensitivity to geographic variation.

4.2 Hydrological Modelling

As suggested earlier, the control of water resources or, more precisely, effective run-off harvesting, is likely to have had a significant impact on site location in Kythera's semi-arid Mediterranean climate, especially if cross-channel terracing was indeed in operation during the Middle-Late Bronze Age.

A GIS can deploy elevation data and stream courses to model hydrology with considerable success (e.g. Mark 1984; Jenson and Domingue 1988; Garbrecht and Martz 1999). The most popular methods of automated analysis involve a global (i.e. applied to the whole DEM rather than to a small window or neighbourhood) characterisation of (water) flow magnitude. By traversing the DEM, it is possible to predict accumulated surface flow (a flow accumulation model), building up a picture of how water might behave on a given landscape and mapping for each grid cell of the terrain model, the number of other cells that are likely to drain through it. From such a model, drainage networks of different scales can be extracted, reflecting those cells with over a certain (arbitrary) threshold of other cells 'flowing' through them.[10]

By comparing the networks produced at different flow accumulation thresholds in the Kytheran data, it becomes clear that the majority of Neopalatial sites seem to be located near to (but rarely, if ever, directly on top of) drainages of a fairly small size (with, for example, less than 5 ha of the surrounding landscape draining into them), rather than to many of the large gorges. This is partly to do with the fact that such smaller-scale networks are comparatively common; but we can nonetheless still model the hydrological character of site locations, for all the Neopalatial sites in the survey area, by plotting the proportion of cells of a certain flow accumulation that have sites on them (Figure 19). The pattern is a significant one ($p < 0.001$) and there is a strong relationship visible in the lower half of the regression in Figure 20. In contrast, the upper half is less clearly defined, not least because it is effected heavily by a) decreasing sample size, b) the inclusion of some cells on the edge of site scatters and covering the beginnings of channels systems, and c) the impact of just one or two sites in unusual locations.

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[10] Hydrological analysis was carried out using TAUDEM (Tarboton 1997) and the CRWR-PrePro extension for Arcview (Olivera et al. 1998). These were used to compare the effect of using alternative D8 and D∞ algorithms for calculating flow direction and accumulation, and the results were reassuringly close. The resolution of the DEM (10 m) is well within an acceptable tolerance suggested by several analyses into the effect of DEM grid size on automated drainage network extraction (Garbrecht and Martz 1999). The TOPOGRID algorithm used to interpolate the Kythera DEM is specifically designed to produce hydrologically correct interpolations (Hutchinson 1989; Hutchinson and Dowling 1991). Stream courses were not included in the interpolation for several reasons: 1) there are no perennial rivers on the island, 2) while there are winter season channels, it is unclear how such drainages were prioritised when the original paper maps of the area were made, and 3) the drainages involved are, for the most part, relatively abrupt.

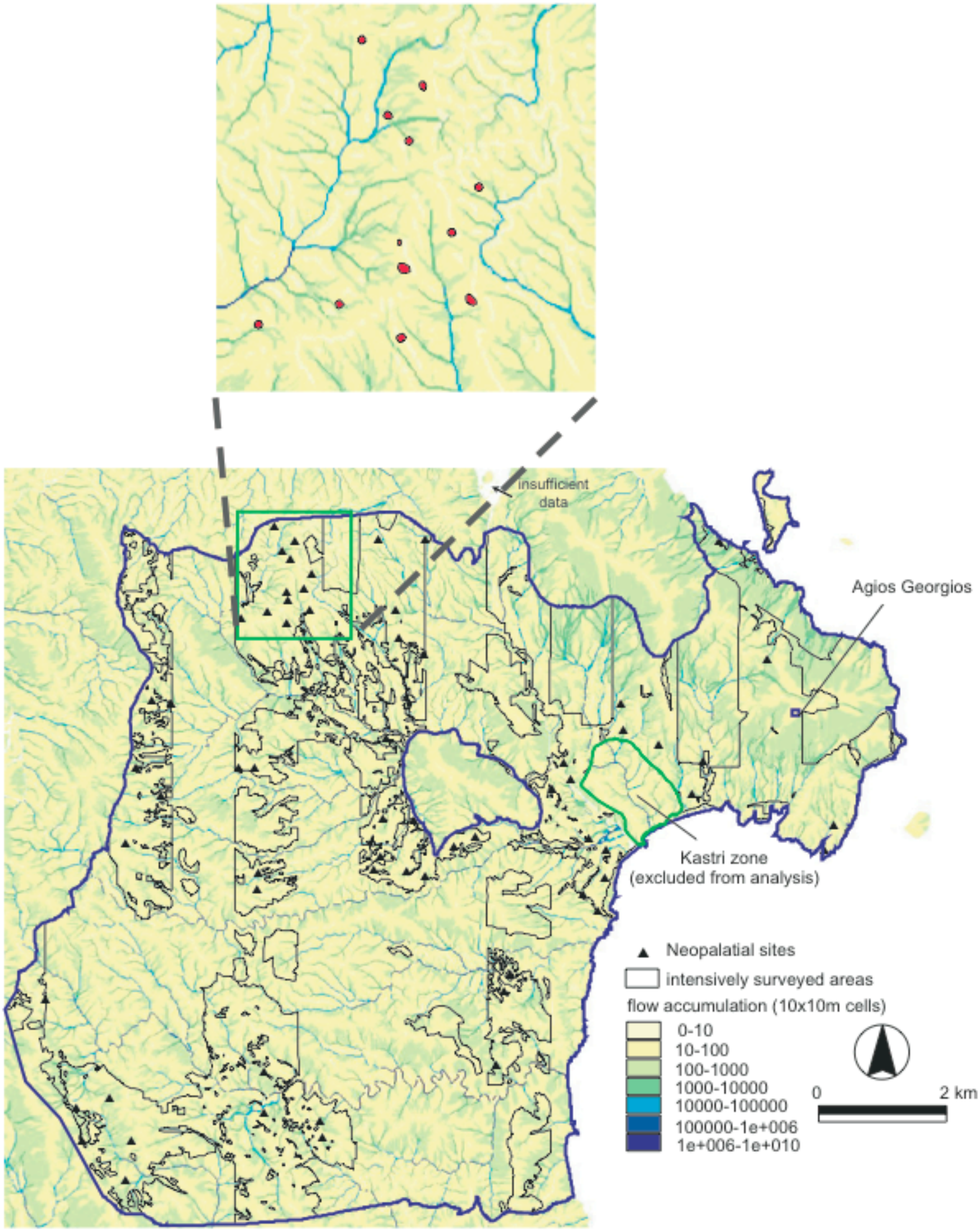

Figure 19. Neopalatial sites and hydrological flow accumulation.

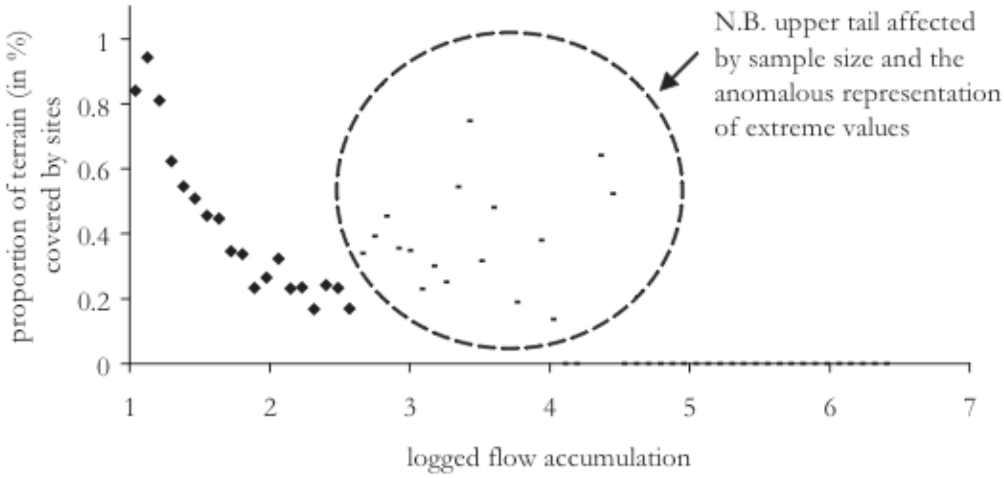

Figure 20. Correlation between Neopalatial sites in the KIP tract-walked area and hydrological flow accumulation.

Another way to map the impact of hydrology on site location is to delineate watershed boundaries. Watersheds are areas that drain through the same outlet point (or node, where stream-lines flow into one another) in the drainage network. As such, they can be explored at a number of different scales in the same manner as the drainage channels themselves. They also make useful heuristic sub-divisions, representing visually obvious, natural basins, often bounded by ridges and sharing the same erosion patterns, similar soil moisture etc. Figure 21 provides an example, once again from the upland plateau region of Mitata. It shows the watersheds for all stream segments that have more than 6.25 ha of surrounding land draining into them. At this scale, it is significant ($p < 0.001$) that *all* of the known Neopalatial sites within the Mitata region are within 50 m of watershed boundaries, and regression suggests a strong linear relationship (Figure 22).

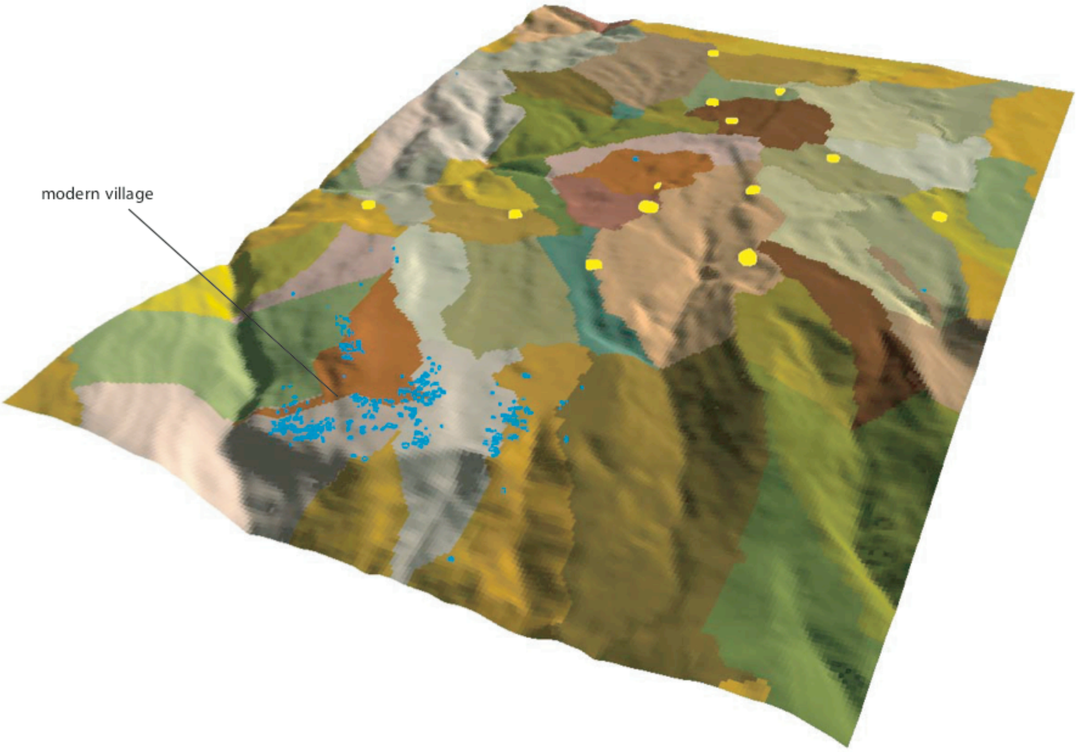

Figure 21. Neopalatial sites and watershed boundaries on the Mitata plateau (minimum basin size of 6.25 ha).

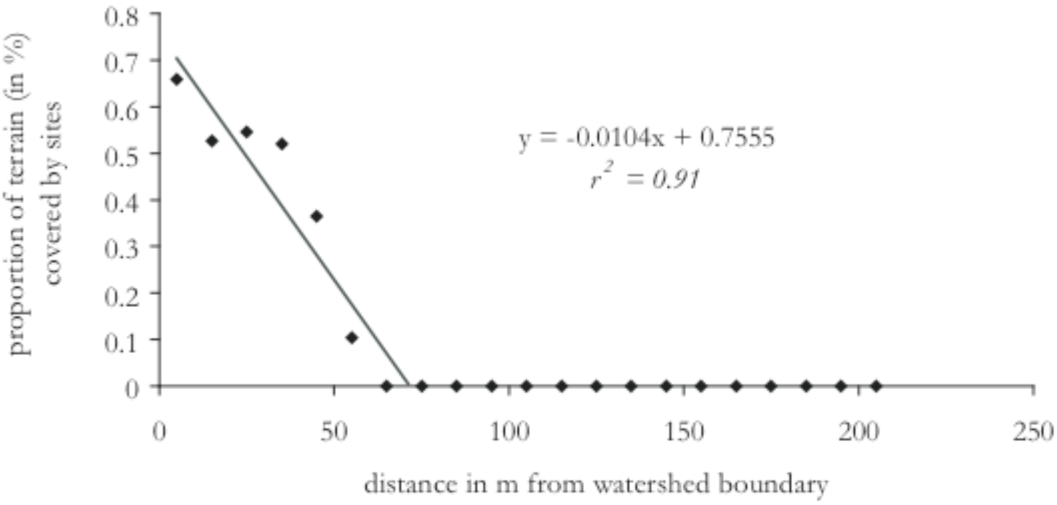

Figure 22. Correlation between Neopalatial sites on the Mitata plateau and distance to watershed boundary.

How might such a site location preference operate in terms of actual human decision-making? A strong correspondence between the location of sites and the edges of watersheds is visible at many different scales, but it is interesting that the hydrological scale (minimum watershed size or flow accumulation of 6.25 ha or 25 x 25 cells) found to be most discriminating corresponds well to the farmstead catchments sizes suggested by site-spacing and ceramic distribution. It suggests that when Neopalatial farmers were considering how far and in what direction to locate new farms in relation to old ones, they may have been thinking in terms of one or two discrete basins of an appropriate size. In addition, proximity to watershed boundaries may also reflect other priorities. For example, locating houses high up in the catchments of the larger watersheds would inevitably place them alongside the smaller, shallower channels of the basin. Under the intensive agricultural model suggested above, these channels would be the most suitable locales for farming. Similarly, the Mitata watersheds in particular are bounded by small limestone ridge-systems. Many of the Neopalatial sites appear to have been using these ridges, perhaps as wind-breaks, animal pens or locations for nearby tombs, but also as structural support against which the farm building itself was built.[11]

5. Island Demographics: Population and Interaction

By exploring site sizes, spacings, possible catchments and locations, we can build up a picture for Neopalatial Kythera of a fairly crowded, but not hierarchically ordered, rural landscape of dispersed family farms and one major primate centre. The following section moves from the discussion of scatters to propose some rough population figures and suggest some further implications these figures might have with regard to the way communities on the island interacted with each other (for a recent volume devoted to population studies with the context of Mediterranean survey, see Bintliff and Sbonias 1999).

Table 1 summarises information about the density of sites in different parts of the tracted area. Some very crude figures for what the overall number of sites for different regions of the island might be (if the observed densities are representative) are also given. However, as we saw in an earlier section, Neopalatial farmsteads are found on particular types of terrain which are not evenly distributed across the island. In fact, our terrain curvature modelling allows us to produce more sensitive estimates. If the relationship between terrain roughness and site location suggested in Figure 20 holds for the survey area as a whole, it would predict 142 sites rather than the 157 rural sites (beyond Kastri) suggested by a simple extrapolation of site density (table 1). This reflects the fact that the tract-walked areas under-sample rougher terrain. We lack the topographic resolution (a 10 m DEM based on 2-4 m contours and spot heights) to formally extend this analysis to the island as a whole, but preliminary modeling confirms that we need to adjust our population estimates *down* by some 10% to account for this sampling bias.

	no of sites	*scatters in ha*	*total area in ha*	*mean scatter size in ha*	*% scatter*	*ha / identified individual site*
tract area	80	55.5	4255.7	0.69	1.3	53.2
Kastri zone	14	38.67	136.2	2.76	28.4	9.7

[11] Sites that appear to be using such scarps include 001A, 012, 014, 027, 047, 085D, 151 and possibly 152. My thanks to Charles Frederick for identifying this likely pattern and discussing it with me.

beyond Kastri zone	66	16.83	4119.5	0.26	0.4	62.4
Mitata zone	12	1.65	174.2	0.14	0.9	14.5
beyond Kastri and Mitata zone	54	15.18	3945.4	0.28	0.4	73.1

*Some simple extrapolated values:**	*total ha*	*estimated no. of sites*
survey area beyond Kastri zone	9793	157
survey area (including Kastri zone)	9936	171
island beyond Kastri zone	27682	444
island (including Kastri zone)	27825	458

* Using a site density of 1 site/62.4 ha suggested by the area beyond the Kastri zone

Table 1.. Summary statistics for Neopalatial settlement within the intensively surveyed tract area and some simple extrapolated values for the survey area and for the island as a whole.

So we should probably be thinking of ca. 400 farmsteads (444 less ca.10%) out in the landscape beyond the Kastri zone. This is a huge number: apart from anything else, it emphasises yet again that intensive survey produces site numbers that are orders of magnitude higher (both the sites actually observed in the tracted area and those implied for the whole island) than extensive reconnaissance of the same landscape (Cherry 1983). If, as suggested above, we make the reasonable assumption that the groups represented by the scatters are typical nuclear (or minimally-extended stem) families of 4-6 individuals, then this suggests a rural population of some 1,600-2,400 people.[12] Given the likelihood that some of the farmsteads were not contemporaneously occupied, it probably best to emphasise the lower end of this range.

What about the population represented by the dense occupational debris in the Kastri zone? Getting any kind of clear picture of how many people lived here is extremely difficult because: a) we seem to be dealing with a mixed landscape of settlement, tombs and possible agriculture; b) we have several areas where riverine activity has either cut away or buried Neopalatial remains; and c) the process of extrapolating from surface scatter to the likely extent of any represented buildings (if any), and thereafter estimating population based on presumed habitation areas, is fraught with difficulties at every stage.[13]

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[12] For discussions of residential family units, see Cook 1972: 13-14; Laslett 1972; Gallant 1991: 11-33; and for likely Neopalatial household structure, see Whitelaw 2001: 17-21.

[13] A.s suggested above, scatters represent not just intra-structural debris, but a range of other activities that can occur very close to, but outside of these built structures. Moreover, the balance between 'inside' and 'outside' debris (the ratio of one vis-à-vis the other as represented in the surface record) is likely to be highly variable not only cross-culturally, but also with respect to the size of settlement involved. The process of estimating urban populations from different aspects of inhabited space has been considered by many commentators with some success, though the importance of tackling such issues from an understanding of culturally-specific

Even so, viewed unsceptically, the total area of *dense* scatter within the Kastri zone is quite large (ca. 40 ha) when compared to contemporary sites on Crete (using Whitelaw's figures [2001: fig. 2.10], only Knossos and Phaistos would be larger); but, as suggested above, the actual built areas involved are likely to have been patchy and considerably smaller. In the excavated area in the Kastri neck, there is evidence for relatively dense occupation (Coldstream and Huxley 1972: fig.9) and we might assume this part of the site to have supported populations similar to those indicated by the better-known layouts at Palaikastro and Gournia (i.e. as much as 250-450 people/ha [Whitelaw 2001: 24-26]). However, beyond this core area, we should expect residential density to be much lower and, at the very margins of the Kastri zone, it may well have almost reached the levels of the rural farmsteads (where we probably have no more than 25-35 individuals per ha of surface scatter). We might therefore cautiously bracket a population of 2,000-5,000 individuals as the likely scale of occupation at Kastri, again probably with a preference for the lower part of this range. Whatever the exact figure, this suggests that despite the many rural scatters, a significant proportion of the Kytheran population resided at the primate centre or its immediate surrounds. Branigan's suggestion (2001: 46-47) that as much as half of the Neopalatial Cretan population was urban may well also be true of contemporary Kythera.

These parameters for Kastri and the rural sites have some general implications. Firstly, they suggest a total population of 3,600-7,400 people in the Neopalatial period. This compares well with the current population of the island (ca. 3,500 people) and the population range of 1,850-14,605 documented in historical times (Leontsinis 1987: 193-94, table 1).

Given these demographic parameters and the fact that rural farmsteads could not have existed in isolation from each other, we can begin to propose scales of interaction between sites (involving both kinship and socially-constructed links), to share farming equipment, trade, intermarry and spread subsistence risk in a variety of ways. This is likely to occur as a matter of course across short distances: for example, given the observed Neopalatial site spacing and a typical 'hailing distance' of ca. 150 m (Roberts 1996: 24, 88), it will have been quite possible to communicate verbally over the distance separating a farmhouse and the edge of its theoretical catchment (or the start of a neighbour's).

However, at these population densities, interaction between sites will also have occurred at medium and longer range as well. For example, the need in any community for individuals to find suitable reproductive partners (not least to ensure demographic viability) demands a certain level of social interaction, usually modelled to involve groups of at least several hundred who come into contact with each other on a periodic basis (e.g. Wobst 1974). On Kythera, such a demographic threshold might be achieved by any given rural family interacting: a) directly with the primate centre at Kastri, b) with at least 50-75 neighbouring

attitudes towards spatial organisation has been increasingly emphasised (Clarke 2000; Whitelaw 2001, with refs.).

farms of nuclear families (4-6 people each; a sufficient number would probably fall within a 4 km radius), or c) by some combination of these two.

Another parameter that may be relevant is access to a market. Some cross-cultural regularity (probably due to land transport costs in pre-modern societies) has been noted in the average distance from any site to the nearest available market centre which suggests that a range of 3-7 km to the nearest market is the norm (Hodder and Orton 1976: 57-58). Given the size of Kythera, it is therefore not unsurprising that throughout its history it seems to have had usually one or, more rarely, two major market centres.[14] For example, most of the island is accessible from Kastri in a one-day round trip, especially if we include the possibility of short maritime journeys. Beyond this, the specific character of Kastri's relationship with the rural sites depends on what kind of political entity we see functioning at the port town (a local ruler, a governing elite group, a Cretan political representative?) and the degree to which it tried to manage Kytheran rural affairs.

At these population levels, Neopalatial Kythera is likely to have been self-sufficient in terms of its normal subsistence requirements and demographically viable without necessarily intermarrying with groups from neighbouring regions. In other words, off-island interactions would not have necessarily been a pre-condition for the community's survival (except perhaps at times of extreme crop failure). Even so, such connections may well have been solicited/imposed from the outside, such as by the Cretan palaces, or encouraged by local elites on the island for reasons of commercial opportunity or prestige. Likewise, off-island factors may well have strongly influenced the type of settlement system prevailing on Neopalatial Kythera. In later periods (particularly the Venetian and British periods, for example, but also perhaps the Classical), written sources highlight the significance of both historically-contingent, off-island events (e.g. the in- and out-flow of refugees during times of unrest in Crete, the Peloponnese and beyond) and policies (e.g. the Venetian taxation system or British agronomic reform) in defining the settlement patterns and land use regimes prominent on the island (Leontsinis 1987). Many of the off-island influences on the Neopalatial landscape are likely to have come from Kythera's immediate neighbours, especially from Crete. However, it would be wrong to think that these were not nested in larger eastern Mediterranean trends relating, at varying temporal scales, to such things as climate change, shared elite consumption patterns and long-distance maritime trade, some or all of which are likely to have had 'knock-on' systemic impacts on the Kytheran landscape.

6. Conclusions

This paper provides a suite of insights into Neopalatial settlement on Kythera by drawing on intensive survey data and the strengths of GIS-led spatial analysis. It has sought to make the interpretative leap from surface remains to actual settlement systems and their implications in testable, quantifiable ways, using a

[14] The existence of two major market centres on Kythera since the Venetian period is in fact an interesting special case, because one of the sites (Chora) was sited on the southern tip of the island and was therefore geographically ill-suited to act on its own as a central market for the island.

range of spatial techniques. Surface survey has revealed a major multi-focal, semi-urban zone at Kastri and a rural landscape of small family farms possessing little or no hierarchical organisation. Rural site-spacing and site-location can be shown to have some regularity which may reflect both the operation of specific intensive agricultural strategies and related to this, choices made when colonising new land. From site numbers, size and GIS modelling, relatively robust estimates of the Neopalatial population can be made.

There is increasing emphasis placed on the critical role of the countryside and its smallest settlement units in the dynamics of Mediterranean life. Future research will need to elucidate whether the patterns described here are a) common to rural subsistence throughout the Bronze Age Aegean and/or with meaningful correlates in other Mediterranean contexts, b) a particularly 'Minoanised' strategy, typical of Cretan-influenced social, political and economic organisation, or c) an ecological adaptation specific to Kythera itself. In any case, the quality of the KIP dataset and its full integration within a GIS environment allows us to go beyond the simple identification of rural sites and to look more broadly at how such places might operate and interact with each other at the landscape scale.

Acknowledgments

This research was made possible by the tenure of a Leverhulme Trust Research Fellowship, held at the Institute of Archaeology, University College London. It draws on a dataset which is the product of collaborative efforts by the many people involved in the Kythera Island Project. My thanks also to Cyprian Broodbank (KIP director), Philip Betancourt, James Conolly, Lin Foxhall, Charles Frederick, Donald Haggis, Paul Halstead, Peter Jordan, Vangelio Kiriatzi, Nancy Krahtopoulou, Clive Orton and Jeffrey Soles for discussion and advice, as well as to the three anonymous *JMA* reviewers.

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