

APPLICATIONS OF REMOTE SENSING AND GIS TO THE INVESTIGATION  
OF PAST SETTLEMENT ON THE ÇARSAMBA ALLUVIAL FAN, ANATOLIA.

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Doctor of Philosophy

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July 2000



I certify that this thesis is my own work

### Acknowledgements

This research was funded by a Natural Environment Research Council studentship.

I am indebted to Dr. Douglas Baird of the University of Liverpool and to Professor Neil Roberts of the University of Plymouth, Chris Place of the Geography Department at Edinburgh, Caroline Evans, Dr. Orrin Shane of the University of Minnesota Science Museum and Dr. Tony Gatrell at the University of Lancaster.

Dr. Trevor Watkins and Dr. Geraint Coles (Archaeology) and Mr Bruce Gittings (Geography) supervised the research. Dr. Iain Woodhouse and Professor Gary Lock gave constructive direction on corrections and improvements to the thesis.

# Applications of remote sensing and GIS to the investigation of past settlement on the Çarsamba alluvial fan, Anatolia.

## Abstract

The settlement history of the Çarsamba alluvial fan is investigated for the interval circa 9,000 - 1000 BP using Geographic Information System (GIS) tools and satellite remote sensing data. Models of landscape and settlement pattern development are evaluated with reference to the archaeological settlement record. Exploratory data analysis methods are used to examine the spatial characteristics of reconstructed settlement distributions.

The use of multi-date Landsat Thematic Mapper (TM) and SPOT Panchromatic satellite data to increase the visibility of past settlements is described within a methodological section of the thesis. Vegetation cover conditions and the contrast between decomposed mudbrick and alluvial soils are identified as important factors in the visibility of settlements. The successful specific detection of previously unrecorded past settlements from Landsat and SPOT data is reported.

The archaeological settlement record of the Çarsamba alluvial fan displays complex spatio-temporal patterning as a result of the interaction of cultural and taphonomic factors. While some features of the archaeological record are artifacts of differential preservation or recovery, others clearly reflect the influence of changing physical environments on past landuse and occupation.



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## Chapter 1: Introduction

The topic of this thesis is the investigation of the long-term archaeological settlement record of the Çarşamba alluvial fan within the Konya - Ereğli basin (37.30 N, 33.00 E), a closed, semi-arid basin located on the Anatolian plateau of south central Turkey at an elevation of 1,000 metres a.s.l. The Konya - Ereğli basin was formerly occupied by a large palaeolake that dried up around 19,000 Cal. BP. The study area centres on the extensive (470 km<sup>2</sup>) alluvial fan lain down by the Çarşamba river where it flows onto the floor of the basin. The fertile and well-watered alluvial soils of the Çarşamba fan have provided a focus for local human populations for over 9,000 years.

The Çarşamba fan was selected for investigation because of its long settlement record and because its archaeological remains are relatively well known. The archaeology and palaeoenvironment of the fan are also presently the subject of intensive research in connection with the renewed excavations at Çatalhöyük, a major Neolithic and Early Chalcolithic settlement mound near the centre of the fan.

Evidence for past settlement activity on the Çarşamba fan is generally in the form of tell mounds or *höyük* (Turk.), man-made mounds consisting of the weathered remains of many generations of superimposed mudbrick structures. Large numbers of such mounds populate the landscape of the fan. Archaeological evidence for past settlement activity also occurs in the form of less obtrusive surface scatters. The objective of the present research was to apply a diachronic approach to the investigation of the archaeological settlement record of the Çarşamba alluvial fan in south central Turkey, using geographic information systems (GIS) to store, manage and manipulate the spatially referenced information required for this analysis.

From the outset it was recognised that the long-term alluvial processes responsible for the formation of the fan would create an environment in which the recovery of the evidence for past settlement is subject to bias as a result of burial beneath later alluvial sediments. A necessary element of the present research was to make some assessment of the nature of this bias, particularly with regard to the preservation of

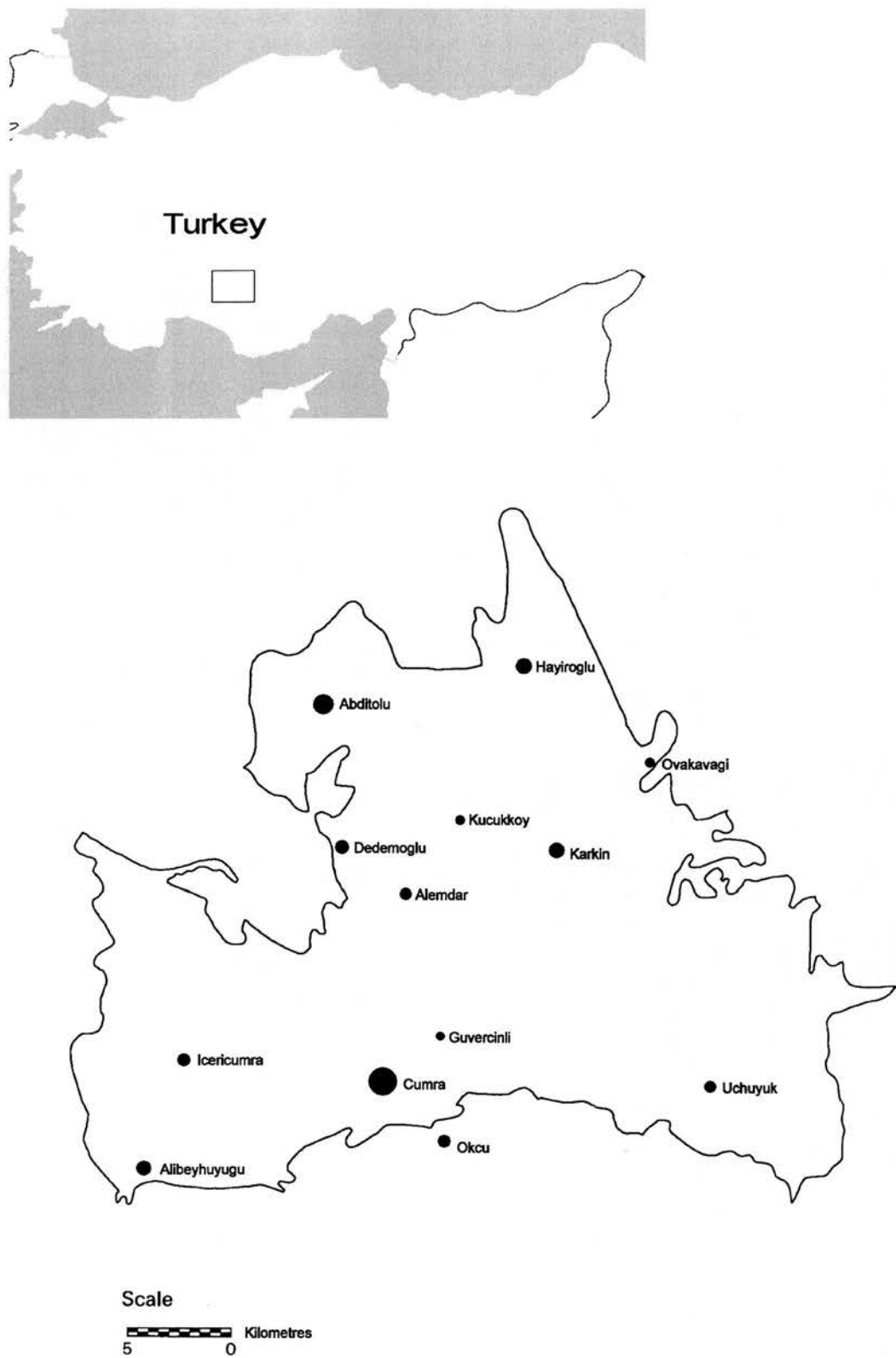


Figure 1.1 General location of Konya - Ereğli basin within Turkey (top) and map showing locations within the Çarşamba fan study area (lower).



the archaeological evidence for past settlement in different parts of the study area. The nature of the archaeological evidence and palaeoenvironment of the Çarşamba fan are accordingly examined in chapters 2 and 3 of the thesis.

Reconstructed settlement distributions for the various archaeological periods, based on the evidence of historic and recent archaeological field surveys, are presented in chapter 4 in the form of maps and descriptions of the main characteristics of settlement in each period. The spatial characteristics of the reconstructed settlement distributions are explored in chapter 5.

A second main theme of this research has been to establish the potential application of satellite remote sensing as a technique to increase the visibility of less obtrusive components of the archaeological settlement record. This topic is examined in chapters 6 and 7. The literature relating to previous archaeological remote sensing applications and the methods used to select and process satellite remote sensing data are described in chapter 6. In chapter 7, the spectral characteristics of past settlements on Landsat Thematic Mapper and SPOT XS imagery are investigated and fieldwork experiments in the specific detection of archaeological features using the data from these sensors are described.

In the concluding chapter (chapter 8) the available evidence is synthesised and interpreted into a reconstructed settlement history for the Çarşamba fan spanning the early prehistoric through Roman and Byzantine period.

## Chapter 2: The Archaeology Of Past Settlement.

### 2.1 Data sources and previous archaeological work on the Çarşamba fan

The main data used here to reconstruct past settlement distributions by period are drawn from the preliminary results of the Çatalhöyük Regional Survey, an ongoing archaeological field survey project begun in 1993 and directed by Dr. Douglas Baird of the University of Liverpool (Baird and Watkins 1994, Baird 1996a, Baird 1996b, Baird 1997). At a small number of sites not yet visited by the Çatalhöyük Regional Survey project, data from earlier archaeological surveys has been used (Mellaart 1955, Mellaart 1958, Mellaart 1961, Mellaart 1963, French 1966, French 1970a).

In integrating new and existing archaeological survey data, it was necessary to consider the research methodology of the original surveyors (Redman 1987). The 1958 mound survey of Mellaart, Hall and French (Mellaart 1961, Mellaart 1963), Mellaart's earlier work (Mellaart 1955: 115, Mellaart 1958), and French's later surveys (French 1966, French 1970a), concentrate on the prehistoric or 'preclassical' archaeology of the area. French describes, for example, how areas to the northwest of Çumra (for locations see Figure 2.1) were purposely given less emphasis in the 1958 survey as they were thought to contain mostly 'late' i.e. Hellenistic and Roman period sites (French 1970a: 139). Mellaart originally planned a complete survey of the Konya plain but abandoned this scheme once the difficulty of visiting remote sites without mechanical transport became apparent (Mellaart 1958: 311).

The published materials from Mellaart's surveys of the Konya basin focus on the Iron Age and earlier archaeology, with later settlement phases generally noted only where they hinder the study of earlier occupations (e.g. Mellaart 1958: 318). French's later fieldwork in the Konya, Çumra and Karaman addressed settlement from the sixth millennium BC into the mediaeval period, but the archaeology of the first millennia BC and AD is brought into a single class, so that separate analysis of Hellenistic, Roman and Byzantine settlement distributions is not possible (French 1966, French 1970a).

It is apparent that Hellenistic and Roman and Byzantine remains on the Çarşamba fan have historically received less emphasis than those dating to earlier times (i.e. before *circa* 2,400 BP). This disparity is expected to influence the reliability and completeness with which settlement distributions are reconstructed. In this chapter, settlement distributions for the Iron Age and earlier periods are compiled from all available data to obtain a comprehensive coverage of the Çarşamba fan study area while Hellenistic, Roman and Byzantine settlement distributions are reconstructed using preliminary data from the Çatalhöyük Regional Survey.

Surface surveys offer the advantage that they can be conducted relatively rapidly, at a regional scale and at a fraction of the cost of excavation (Dunnell and Dancy 1983: 270). However, potential pitfalls in the reconstruction and interpretation of past settlement distributions from survey evidence are well documented (e.g. French 1970a, Adams 1972, Flannery 1976, Kirkby and Kirkby 1976, Schiffer et al 1978, Bintliff 1988, Altschul and Nagle 1988). Where data from different sources are collated, the potential influence of the different research methodologies used to collect archaeological evidence should be considered (e.g. Kvamme 1988a: 301-302).

The nature of the archaeological record of past settlement activity on the Çarşamba fan is now described with emphasis on the issue of recovery bias and the extent to which reconstructed patterns are likely to be representative of actual past settlement distributions. An outline chronological framework for past settlement on the Çarşamba fan is also presented.

## 2.2 The archaeological evidence for settlement

The objective of the present study is the analysis of the distribution and location of past settlement. In order to study past settlement distributions, it is necessary to reconstruct patterns of settlement activity for different times in the past. The reconstruction of past settlement distributions is accomplished by collating the archaeological evidence for past settlement activity from surface artifact assemblages

at a large number of past settlement sites. In interpreting this evidence, it is necessary to consider the nature of the archaeological settlement record both at the site level and at the level of the study region.

Schiffer et al (1978) define some parameters that may be used to describe the distribution of archaeological entities within a given setting. Using this scheme, the frequency or prevalence of a material or feature is its abundance, expressed in terms of a number per unit area. Clustering is defined as the degree to which archaeological materials are spatially aggregated. Visibility is a characteristic of the extant environment, and includes factors such as the concealment of archaeological sites or materials beneath later sediment or vegetation cover. Obtrusiveness is the product of the interaction between the physical properties of an archaeological material or feature and the methods used for its location (Schiffer et al 1978: 6-7). Here, the abundance and clustering of past settlements sites is discussed along with other spatial characteristics in chapters four and five. The following section is concerned with the visibility and obtrusiveness of the archaeological evidence for settlement on the Çarşamba fan.

The significance of the Çarşamba fan as a focus for local human populations over the past several millennia is evident from the many abandoned settlement mounds it contains. These range from small sites of less than one hectare in extent barely raised above the surrounding fields, to immense mounds of over thirty hectares and 20 metres or more in height (Figure 2.2). The largest mounds contain many generations of structures and multi-phase settlement histories are a common feature at such sites.

The necessary condition for the formation of a tell mound or *höyük* is a high net rate of sediment accumulation, the product of highly nucleated and densely populated settlement over a long period, where mud brick forms the main building material (Davidson 1973). Where the settlement layout is more open or dispersed in character and occupation is of sufficiently short duration, or where mud brick is less extensively used as a building material, tell mounds may not be formed.





Figure 2.1 Different sizes of tell mound or hoyuk. (top) Turkmenkarahoyuk on the eastern edge of the study area. (lower) General surface collection at Musluk Huyuk, a small Chalcolithic period settlement site located from satellite imagery. Note the contrast between the lighter site soils and the surrounding natural alluvium.

The influence of settlement layout on tell formation can be seen in some modern villages on the Çarşamba fan, as for example at Karkın, Dedemoğlu and Ovakavağı, where centuries of traditional mud brick construction have produced no appreciable tell deposit. Processes of tell formation and erosion are discussed in detail by Rosen (1986), Kirkby and Kirkby (1976) and by Davidson (1973, 1976).

The successful reconstruction of the occupation history at multi-period mounds depends on the recovery and identification of material derived from buried occupation phases within a surface-collected sample dominated by material of later date. The depth to which an early occupation phase is buried by later material will influence the prospect of recovery under such circumstances. Quantitative modelling suggests that less than 1 per cent of the ceramic material from an occupation level buried to a depth of five metres will be re-deposited at the tell surface through incorporation into the mud brick fabric of later structures (Kirkby and Kirkby 1976: 244-246). The potential under-representation or even non-recognition of early occupation phases is therefore an issue at multi-period mounds mantled with deep occupation deposits.

Evidence of past settlement activity is also found in the form of unobtrusive 'flat' sites. The already low visibility of these sites is further reduced at times of year when they are covered by growing crops. Flat sites on the Çarşamba fan frequently prove to be of Iron Age and later date, but no reliable relationship between site type and occupation period exists as flat sites of earlier date are also found. Apparent 'flat' sites in some areas of the fan are likely to be the upper regions of low mounds that are largely buried by later alluvial sediments.

The total pedestrian survey coverage of an area such as the Çarşamba alluvial fan, measuring hundreds of square kilometres, is a practical impossibility with the result that even extensive flat sites may be missed. It can also be difficult to establish the extent of sites under conditions of reduced ground visibility in the presence of crops and other vegetation. In the present project, flat sites were found near known sites during mound surveys, by field-walking locales with the *Mevki-i* place-name suffix



on the map, on information from local informants, or by remote sensing. The pattern of recovery of flat sites and artifact scatters suggests that these are likely to be under-represented in comparison to the more obtrusive raised settlement mounds.

Ceramic sherds comprise the overwhelming part of the archaeological material found at hüyük and flat sites on the Çarşamba fan. The size and nature of the surface sherd collection at each site will influence the recognition of the diagnostic typological variation important for dating. The recovery of rare components within a surface assemblage, including traces of early settlement in the form of potsherds re-deposited from deeply buried occupation levels, and of less common stylistic traits important to typological dating, is expected to be sensitive to sample size (Kintigh and Ammerman 1982).

Both the total area sampled and the overall size of the sample collected are likely to be greater at large mounds than at smaller sites. In terms of the proportion of the site surface sampled, more of the site surface will tend to be collected at smaller sites (Redman and Watson 1970). Systematic variations in the nature of the surface-collected sample obtained at different types of site may affect the effectiveness of typological dating and potentially bias the reconstruction of settlement in some periods. The overall condition of an assemblage is also important. The relatively well-preserved material found eroding from the slopes of an uncultivated mound will retain a higher level of diagnostic detail than the more heavily abraded and fragmentary assemblages typically recovered from a plough-soil context. The interaction of preservation and sample size factors is therefore expected to influence the recovery of settlement evidence in complex fashion because it affects the completeness and accuracy of dating at different types of site and of specific occupation periods, even where a consistent sampling methodology is applied.

It is useful to distinguish between the task of detecting past settlements, i.e. locations at which evidence for past settlement activity is found, and the task of reconstructing the occupation history of such settlements. In the same way that not all components of past material cultural assemblages are equally obtrusive, so it is apparent that not

all forms of past settlement will be recovered with equal success. Settlement activity in some periods may be inherently harder to detect because of the nature of the settlement activity itself.

The size distribution of settlements within a distribution will also affect how completely that settlement distribution is recovered. In most field survey contexts, it is apparent that settlements of small area are less likely to be located than larger ones given the same intensity of survey effort (e.g. Schiffer et al 1988: 6). The reliability of reconstructed settlement distributions is therefore expected to diminish rapidly for sites below some minimum size, which it may be difficult to determine with precision (Bintliff 1997).

In the intensively cultivated alluvial landscape of the Çarşamba fan, settlements such as Çinili, Kartaltömeği II, Kerimin Adası, Deliali, Sarlak II and Karkın Mezarlık II are probably below the minimum size threshold for reliable recovery. The sample of similar-sized sites recovered from survey may represent a small proportion of the original population that existed on the fan. Similar challenges are presented by single-period settlements, which are often smaller and less obtrusive than multi-period mounds. As a result of these factors, the pattern of recovery for past settlement distributions containing a high proportion of single-period sites or sites of small area is likely to be different to that obtained for one composed of large or multi-period sites.

Mounds at the lower end of the recorded size range are vulnerable to destruction and subsequent loss from the archaeological record as a consequence of modern intensive agricultural land use. The small Chalcolithic mound site of Bozlan Höyük illustrates this process. The position of Bozlan Höyük is marked by a symbol on maps printed in the 1940s and early 1960s, but is replaced by a name in the general location of the mound on the 1992 map sheet. During a field visit to relocate and survey Bozlan Höyük in 1997, field workers confirmed that the mound was levelled some years earlier to improve the crop field in which it stood. The site now exists as a field scatter extending over an area measuring approximately 100 metres by 150 metres.



Numerous other small hüyükü may have been levelled in the period since the widespread adoption of mechanised agriculture across the Çarşamba fan in the early 1950s.

In alluvial areas, the deposition of alluvial sediments is expected to play a major part in site preservation and visibility (Brookes et al 1982). The pattern of Quaternary alluviation on the Çarşamba fan has been complex and the preservation of past settlement sites is expected to vary with both location on the fan and period. A more precise knowledge of the nature and timing of key events in the formation history of the fan would contribute to the interpretation of the past settlement distributions reconstructed from field survey evidence.

The potential value of remote sensing as a means to improve the recovery of elements of the settlement record that may be missed by traditional mound surveys has already been noted. These elements include small sites, i.e. those perhaps less than one hectare in extent, and also flat sites and artifact scatters (e.g. French 1970a: 141). The use of multi-date remote sensing to explore the variation in the visibility characteristics of past settlement sites at different times of year and the use of satellite remote sensing data to detect 'flat' sites is discussed in Chapter 7.

### 2.3 Reconstructing past settlement activity

The differential recovery of the archaeological evidence for past settlement presents a potential source of bias in attempts to reconstruct the distribution of past human populations. The principal factor affecting the recovery of early settlement evidence on the Çarşamba fan is the extensive alluviation that has occurred since circa 8,000 BP, burying earlier land surfaces and settlement remains. Some features in the recovery of the archaeological evidence for past settlement can be anticipated. One expected characteristic is that settlements from early periods will be more deeply buried than those of later periods (Roberts 1980: 233) and are consequently less likely to be identified by surface survey. A second expected characteristic is that the

number of recorded early sites will increase with proximity to the fan margins, where the depth of alluvial material is lowest.

Studies of the post-Neolithic alluvial history of the Çarşamba alluvial fan have highlighted its complex sedimentary history and also the difficulty of making quantitative statements about the relationship between specific locations, archaeological parameters and alluvial processes. In the absence of more detailed information the soils map of the Konya-Ereğli basin compiled by de Meester et al (1970) remains a logical starting point for any attempt to evaluate the visibility of archaeological remains within the individual sedimentary units of the fan.

Changes in the number and distribution of early sites in relation to later ones are traditionally interpreted entirely in terms of population dynamics and settlement patterns (e.g. Mellaart 1963, French 1970). It is important to recognise however that the statistical interdependence between early and later site locations may be equally significant in shaping reconstructed settlement distributions. Features in the observed temporal or spatial patterning of reconstructed settlement activity, including the 'evidence' for an exponential increase in site numbers over time, can be wholly or partly artefacts of the progressive loss of information about older sites (Kirkby and Kirkby 1976: 248). For some prehistoric and protohistoric periods, the limited knowledge of contemporary material culture and reliance on restricted diagnostic type-assemblages may be critical factors in the visibility of past settlement activity.

In alluvial settings, there is a danger that insufficient attention is paid to the impact of geological processes on the archaeological record that is used to reconstruct ancient settlement patterns and past environments (Brookes et al 1982: 299). In the absence of an understanding of the age and history of landform surfaces, patterns of site distributions and correlations between cultural variables and environmental features may arise solely through factors of geomorphic history (Dunnell and Dancey 1983: 271). The higher proportion of classical sites on the upper Çarşamba fan has been identified as one example of an 'archaeological' distribution which may be better explained by geological processes, i.e. variation in sedimentation rates and in the

locales where alluvial deposits are being formed, rather than cultural factors (Roberts 1983: 347). It is evident that information on the age and formation history of the individual sedimentary units that make up the modern landscape of the Çarşamba fan may influence the interpretation of archaeological survey results.

## 2.4 Dating past settlement activity

Detailed and reliable information on the date and duration of past settlement activity is clearly fundamental to the study of change in human settlement distributions over time. Where the aim is to investigate settlement distributions, it is particularly important to establish whether settlements dated to the same period are truly contemporary (Adams 1965). In view of the importance of adequate chronological control in the study of past settlement distributions, some issues affecting the dating of past settlement remains on the Çarşamba fan are now considered.

The application of absolute or derivative dating techniques, i.e. precise, quantitative age determinations obtained through the measurement of some time-dependent quantity (Aitken 1990), is generally restricted to excavated material within secure stratigraphic contexts. The surfaces of past settlement mounds typically represent unstratified situations, although stratified deposits may be locally exposed through erosion or other factors. In the absence of excavation, emphasis has traditionally been placed on ceramic typology as the most widely applicable technique for dating past settlement activity in such situations (e.g. Mellaart 1957, Mellaart 1961, Mellaart 1963, French 1967, French 1970). This reliance on typological dating has implications for the precision with which past settlement activity can be dated.

Typological dating is based in the expert interpretation of the characteristics of ceramic and non-ceramic materials with reference to cultural assemblages from archaeological excavations and other securely dated proveniences. The technique depends on the recognition of known artifact types and diagnostic features, on analogy with related assemblages, and not infrequently on intuition, observation and guesswork (French 1970: 141). Where dating hinges on the evidence of a small

number of potsherds, the process of assigning a date can be highly judgemental. This is especially true for periods and areas in which ceramic assemblages are poorly known, or where the diagnostic features on which dating is based are uncommon or otherwise difficult to determine.

Relatively few settlements have been excavated in the western Konya basin and it has been necessary to construct typological dating frameworks largely by analogy with the excavated materials from sites in adjoining areas and through the seriation analysis of surface collected assemblages. The poor resolution that is often available from typological dating places limitations on the extent to which contemporaneous settlement distributions can be reconstructed, but there are other sources of uncertainty in the use of ceramic and other materials as a proxy for past settlement activity. These include the potential non-recognition of material dating to some periods, the significance or otherwise of stylistic or technological developments in terms of parallel social or cultural structures (Mellaart 1980: 225), and the extent to which analyses based in the judgement and experience of individual ceramic specialists are capable of duplication by other workers.

In his survey of the Diyala Basin, Adams observed that the proportion of sites dated to the same period but not occupied simultaneously is expected to increase according to the duration of the individual period (Adams 1965: 64-65). In the longest ceramic phases, the contemporaneity of apparently 'neighbouring' settlements is most in doubt. The poor temporal resolution available from ceramic typological dating in some periods is offset to some degree by the knowledge that large *hüyüks* are likely to represent centuries or even thousands of years of occupation activity (Davidson 1973). However, the use of a coarse periodised dating framework results in lengthy spans of undifferentiated time during which the abandonment and/or reoccupation of settlements would not be detected.

The duration of individual ceramic periods ranges from a few centuries to more than a millennium. Dating on ceramic typological grounds is therefore more or less informative in terms of reconstructing settlement distributions, according to the

duration of the period concerned. An additional factor is that the ceramic material collected at mounds need not relate to occupation. A practice of later interment into archaeological mounds is widespread on the Çarşamba fan, and seems to have been especially prevalent during the Roman and Byzantine periods. Settlement mounds close to modern villages continue to be used as burial grounds, as for example at Alibeyhüyüğü, Karkın, Sarlak, Üçhüyük and Çumra.

Some mounds revisited by the Çatalhöyük Regional Survey project have produced evidence for additional occupation phases beyond those recorded by earlier surveyors. The results of different surveys of the same locations can also be in conflict. This situation can result from the transposition of survey records (Kvamme 1988a), but may also reflect different interpretation of the ceramic evidence. Uncertainties also arise from the limited knowledge of ceramics in some periods. The local ceramic repertoires of the Early Bronze Age III period and second millennium through early Iron Age are, for example, less well known than those of the Roman period.

In areas and periods for which excavated ceramic assemblages are unavailable, the discovery of single period settlements becomes important. The value of such settlements is that they have been occupied over relatively short periods and have the potential to provide ceramic material that is useful in the construction of type-assemblages.

The lack of a published locally excavated Early Bronze, second millennium B.C. and Iron Age ceramic sequence remains a significant obstacle to improved temporal resolution within the Konya basin using ceramic dating. The internal division of the Early Bronze period on ceramic typological grounds remains particularly elusive, as the pottery from this time tends to occur within mixed-period assemblages and some stylistic features may span more than one archaeological period. As Mellaart noted in his review of the Early Bronze Age pottery of the Konya plain almost four decades ago “...without a stratified pottery sequence it is impossible to distinguish between EB 1 and EB 2 pottery, but such a distinction is nevertheless highly desirable as these

two periods span a minimum of seven centuries and perhaps as much as a whole millennium” (Mellaart 1963: 210).

The mapped distribution of Early Bronze I and II mounds on the Konya plain may represent a more complex and variable sequence of settlement activity than can be reconstructed on the basis of the coarse temporal framework presently available. In the absence of a locally excavated Early Bronze I and II ceramic sequence, Mellaart suggests that as many settlement mounds are assumed to have been abandoned at the end of the Early Bronze II period the majority of the material at their surface should be of Early Bronze II date (Mellaart 1963: 232).

Non-ceramic materials can also be important in dating settlement activity, particularly at multi-period settlements where aceramic occupation levels may potentially be buried beneath later deposits. Lithic material recovered at the surface of multi-period settlements is likely to have been re-deposited through incorporation into mud brick or similar materials in the course of later construction activity. In the absence of systematic sampling, such unobtrusive components of the settlement record are unlikely to be recovered during low intensity general surface collections or by purposive ‘grab’ sampling (Redman 1987).

## 2.5 Settlement size and past land use

Accurate estimates of settlement size are difficult to make from surface observations. In the case of multi-period mounds, the extent of earlier occupation surfaces cannot be observed directly. Additionally, cultural material may be reworked in later periods to produce a surface distribution that does not reflect the original depositional context. In alluvial environments such as the Çarşamba fan, the burial of the lower slopes of mounds by later sediments further complicates the estimation of settlement size, because the visible area of a mound may be considerably smaller than its original extent.



Estimates of the intensity of past land use surrounding individual settlements have been made through the quantitative analysis of the surface artifact scatters (e.g. Wilkinson 1982, Gaffney et al 1985, Gillings and Sbonias 1999). In the case of mounds in the western and central Çarşamba fan, the density of surface finds generally decreases abruptly with distance from the mound. At the large mounds of Kızlar Hüyük and Tekke Hüyük for example, the distribution of Early Bronze sherds extends for just a few tens of metres from the lower break of slope of the mound. The most probable explanation for this abrupt decrease in the surface density of ceramic material is masking by later alluvial deposits. Where extensive potsherd scatters are found away from mounds they are often of Iron Age, Hellenistic or Roman and Byzantine date.

At multi-period mounds, it is generally not possible to reliably estimate settlement size for different times in the past (French 1970). While mapping the surface distribution of materials by date at a mound may provide additional spatial information about settlement activity in different periods, in the absence of knowledge about post-depositional processes the interpretation of such data is at best tentative (Redman 1987: 251). Patterns of production, use and curation of ceramic material may also have varied over time, complicating direct comparison across different time periods.

For these and other reasons, simple impressions or counts of potsherd densities seem unlikely to yield a reliable indication of the relative intensity of past occupation activity in different periods. Although the form of an individual mound may contain clues about its construction or history (e.g. Davidson 1976, Kirkby and Kirkby 1976, Rosen 1986), excavation and detailed stratigraphic analysis are the only means by which these can be established. Post-depositional processes such as weathering and the extent to which earlier occupation levels are reworked in later periods will clearly influence the distribution of artifacts recovered at the surface in transects or sample squares (Rosen 1986).

Brookes et al suggest a formula for calculating the original area of mounds under conditions of partial burial using a simplified model of mound geometry and information based on the height of the mound and its depth of burial (Brookes et al 1982: 298 Figure 11) The practical difficulties met in applying this formula illustrate some of the uncertainties inherent in estimating past settlement size, A major constraint is the need for information on the depth of burial, knowledge that may not be available in many situations. The modern slope angles of archaeological settlement mounds can also give a misleading impression of their original extent (Brookes et al 1982: 296). This is a particular problem in intensively cultivated areas, where the slopes of mounds are often truncated or otherwise modified.

Rosen (1986) describes how erosion may act to produce steeper slopes on some aspects of a mound and the reduction of slope angles elsewhere. Significant variables include the aspect of the slope with regard to prevailing weather, the nature of the mound matrix, and the undercutting of mound slopes by stream channels – past and present. At Çatalhöyük East, colluvial deposits on the northern slopes of the East mound range in depth from less than a centimetre at their upper edge to over a metre at the lower break of slope (Boyer pers. comm.), further illustrating the difficulty of calculating the original extent of part-buried mounds from observed slope angles in the absence of stratigraphic information.

Any attempt to link settlement size to population levels raises other issues. An important consideration is that the occupied area of a large multi-period mound may be reduced in some periods, so that modern size is an unreliable indicator of relative importance at a specific time in the past (French 1970a: 142). The interpretation of the significance of individual sites within past settlement distributions can be complicated by this consideration.

## 2.6 Settlement chronology of the western Konya basin

The broad cultural - technological designations used to describe Anatolian prehistory and proto-history, such as Chalcolithic, Bronze Age and Iron Age, even when



subdivided into early and late, or I, II, III etc, span lengthy epochs with imprecise beginning and end dates (Joukowsky 1996). The use of such designations can also mask variation in typological dating criteria applied by individual specialists.

The traditional terminology of Anatolian late prehistoric archaeology has been criticised for failing to reflect important characteristics of the settlement patterning and socio-economic and cultural development of the fourth and third millennium BC. Yakar identifies the 'arbitrary' division of the Anatolian Late Chalcolithic and Early Bronze I period, and the tripartite division of the Early Bronze Age as classifications that could be replaced by a more descriptive scheme. (Yakar 1985: 3). The conventional terminology is used here.

The archaeological excavations at Çatalhöyük, Can Hasan and Karahöyük Konya have established local ceramic sequences for the western Konya basin from stratigraphically controlled contexts. Indeed, the need for a secure ceramic sequence for the Konya plain Chalcolithic has been cited by the excavator as a factor in the decision to begin excavations at Can Hasan (French 1998: 1-2). The assemblages derived from these excavations provide the main body of local material available to develop ceramic typological dating schemes for the western Konya basin.

Similarities between the ceramic assemblages recovered by surveys and those excavated at archaeological sites elsewhere in Turkey, for example at Tarsus, Mersin, and Hacilar, have also been used to assist the dating of pottery (Mellaart 1958: 318, French 1967: 174-175). In the case of more distant sites however, regional variations in ceramic production limit the value of direct comparison, as the dynamics of the local introduction and duration of particular stylistic traits remain unknown (Mellaart 1958: 326, Mellaart 1963: 210).

The aceramic Neolithic of the Konya - Eregli plain is known from the site of Asıklı Hüyük, originally recorded by Todd and located on the Melendiz Çayı, 25 km southeast of Aksaray (Todd 1966). Also from the excavations by French at Can Hasan III - where a series of sixteen uncalibrated radiocarbon dates indicated the first

settlement of the site during the mid-seventh millennium BC and its abandonment during the first quarter of the sixth millennium BC (Aurenche and Evin 1987).

Mellaart's excavations at Çatalhöyük and French's excavations at Can Hasan near Karaman produced detailed information on Neolithic and Chalcolithic cultural assemblages with associated radiocarbon dates. The upper occupation levels at Çatalhöyük East - Mellaart's level VII - were dated to the early sixth millennium BC, with the earliest levels (X through XII) possibly of early seventh millennium date, based on radiocarbon age determinations made at the time of the original excavations in the early 1960s.

A series of twenty-six radiocarbon dates on material from the Neolithic occupation levels excavated by Mellaart on the Çatalhöyük east mound range from 6200 to 5,500 BC (uncalibrated, 5568 yr half-life). The earliest village settlement on the site may date from the seventh millennium BC (Aurenche and Evin 1987: 705-706). A 570 year tree-ring sequence constructed by Newton from charcoal recovered from levels VI and VII during Mellaart's excavations at Çatalhöyük has been dated to the interval 7020 BC  $\pm$  50 to 6500 BC  $\pm$  50 calibrated using wiggle matched high precision AMS dates (Newton 1996).

The Early-Middle Chalcolithic in the western Konya basin is dated to the sixth millennium BC on basis of dates from Can Hasan I, level 2B, with the beginning of the Later Chalcolithic placed at *circa* 4500 BC calibrated (French 1967: 174, Aurenche and Evin 1987: 704). The upper levels of the Çatalhöyük west mound produced pottery resembling the Can Hasan I level 2B wares recorded by French, suggesting that these were occupied at around the same date. A second and earlier group of wares from Çatalhöyük, Mellaart's Çatal Hüyük West ware, indicate an earlier Chalcolithic period settlement that pre-dates Can Hasan 2B (Mellaart 1961: 177-184, Mellaart 1965).

There is evidence of some continuity in the ceramic repertoire of the Konya plain during the Late Chalcolithic and Early Bronze Age I periods (Mellaart 1963). Taken

together, the Late Chalcolithic and Early Bronze Age I span perhaps ten to twelve centuries within the interval c. 4000/3800 BC to c. 2800 BP.

The Early Bronze II period, (locally c. 2800 to 2400 BC?), sees the appearance of the first true 'urban' development, in the sense of town sized settlements with central administration, organised economy and public building. Mellaart has proposed that many of the settlement mounds on the Konya plain were abandoned at the end of this period.

Later periods are less well known from locally excavated material within the Konya basin. Excavations at the large Middle Bronze mound of Karahöyük, on the southwestern limits of the city of Konya may yet provide a detailed ceramic sequence for the Early Bronze through Middle Bronze period. Excavations conducted at this site since 1953 have documented twenty-seven occupation levels, the upper four being of Middle Bronze date and the remainder described by the excavator as an uninterrupted Early Bronze Age sequence (Yakar 1985: 214). Unfortunately the ceramic material from this important excavation remains unpublished, although preliminary reports and a volume on the cylinder seals and small finds have been produced (Alp 1972).

Variable dates are proposed for the beginning and end of the Anatolian Early Bronze Age and the level of dating evidence is such that it remains possible to propose radical chronologies through links with Mesopotamia and Egypt (James 1991). The limited archaeological evidence for the terminal Early Bronze Age III period on the Konya plain has led Mellaart to describe it as an Anatolian 'Dark Age', spanning the several centuries from the end of the EB II until the beginning of the MBA at around 1950 BC (Mellaart 1963: 236).

The end of the Anatolian Bronze Age is associated with the collapse of state level political entities throughout the eastern Mediterranean at around 1200 BC and with the proto-historic date for the fall of the Hittite capital Hattusha in c. 1180 BC (Bittel 1983, Drews 1993). The ensuing Iron Age spans the interval from the collapse of the Hittite empire to the beginning of the Hellenistic period around 330 BC. The

combined Roman and Byzantine period extends from the early first century AD until the eleventh century.

Approximate Dates	Period Designation
<7000 - 5500 BC	Neolithic
5500 - 4500 BC	Early Chalcolithic
4500 - 3400 BC	Later Chalcolithic
3400 - 2100 BC	Early Bronze I - II
2100 - 1950 BC	Early Bronze III
1950 - 1200 BC	Second Millennium
1200 - 330 BC	Iron Age
330 BC - AD 25	Hellenistic
AD 25 - AD 1071	Roman and Byzantine

Table 2.1 Guide to archaeological period designations for south-central Anatolia

Sources: Aurenche and Evin 1987, Bittel 1983, French 1967, Gorny 1989, Joukowsky 1996, Kuhrt 1995, Kuniholm et al 1996, Manning 1995, Mellink 1965, Mellink 1992, Yakar 1991.

An absolute Near Eastern chronology, independent of the uncertainties associated with radiocarbon calibration and the interpretation of historical sources, has proven elusive (Renfrew 1996), although the potential of tree-rings for archaeological dating in Anatolia has been recognised since at least the early 1960s (Young 1958, Bannister 1970, Dean 1986). Work since the mid-1970s has demonstrated the feasibility of this technique (Kuniholm and Striker 1983, Kuniholm and Striker 1987, Kuniholm et al 1996), but absolute calendrical dating for Anatolian prehistory is not yet possible using tree-rings. The long Bronze and Iron Age sequence constructed by

Kuniholm and co-workers is perhaps the most archaeologically significant application of dendrochronological techniques and its completion would have wide ranging implications for near eastern chronology (Renfrew 1996: 733).

## 2.7 Summary

The surface of the Çarşamba alluvial fan includes land surfaces of differing age and derivation, and complex patterns of differential preservation and recovery of the settlement record are likely to exist according to parameters of site age, type, size and location.

The archaeological evidence for past settlement often occurs as complex mixed-date assemblages at multi-period mounds. The ceramic typological framework used to date much of the settlement history of the western Konya basin generally fails to provide adequate temporal resolution for the detailed study of past settlement distributions. This is particularly true of prehistoric periods where the beginning and end dates of ceramic typological periods remain imprecise.

It is apparent that the settlement distributions reconstructed for different periods cannot be considered simple equivalents for the purpose of comparison. The length of the archaeologically undifferentiated epochs to which individual artifacts are assigned on typological grounds may be as short as a few centuries or more than a millennium.

The need for improved temporal control is particularly apparent when the alluvial geomorphology of the Çarşamba fan is considered. Alluvial fans are dynamic settings in which environmental variability on decadal and even annual timescales may exert a powerful influence on settlement patterns.

It is apparent that the archaeological evidence for past settlement must be interpreted in the light of knowledge about the limitations of surface-collected assemblages. Continuity of occupation cannot be established with confidence in the absence of

high-resolution temporal information. Similarly, occupation is inferred from the material assemblages at the surface of mounds, rather than demonstrated by excavation. In terms of the continuity or contemporaneity of settlement activity at individual locations, it is not possible to establish from surface survey evidence whether occupation at individual sites is continuous within or between successive periods, nor whether occupations at sites assigned to the same period are truly contemporary.

## **Chapter 3: Palaeoenvironments of the Çarşamba Alluvial Fan**

### **3.1 Introduction**

The archaeological settlement record of the Çarşamba fan extends over an interval of more than nine millennia. A detailed knowledge of the Holocene geomorphology and hydrology of the Çarşamba fan and of past climatic conditions is relevant to the interpretation of past settlement distributions over this period. Alluvial fans are recognised as complex landforms, subject to a wide range of physical controls, the significance of which may be difficult to interpret in terms of the effect each produces (Rice 1977).

The formation history, palaeohydrology and palaeoclimate of the Çarşamba fan are important with regard to understanding the past physical environments experienced by past human populations. In practice, these aspects of the physical environment are interdependent to the extent that it becomes increasingly difficult to discuss any one without reference to the others. The formation history, paleohydrology and palaeoclimate of the fan will nonetheless be approached as separate topics in the first instance to facilitate the organisation of the material, before a summary of the available evidence for past environmental conditions is attempted in the final section of the chapter. Dates cited in this section are uncalibrated radiocarbon dates, unless otherwise indicated.

### **3.2 Formation history of the Çarşamba fan**

In the previous chapter it was observed that the partial or complete burial of the archaeological evidence for past settlement beneath later alluvial sediment is likely to be a major factor affecting the recovery of settlement distributions from the Çarşamba fan. In alluvial settings such as the Çarşamba fan, it is therefore important to consider the chronology and genesis of the sedimentary units as a part of the interpretation of archaeological survey results (Waters and Kuehn 1996, Brookes et al 1982: 285). While a detailed and complete formation history has yet to be




developed for the Çarşamba fan, the geomorphology of the fan and that of the wider Konya basin has been the topic of extensive study (e.g. de Ridder 1965, Driessen and de Meester 1969, de Meester et al 1970, Erol 1978, Roberts 1980, Roberts 1982, Roberts 1983, Roberts et al 1996, Boyer et al 1997, Roberts et al 1999, Boyer 1999).

An outline of the formation history of the Çarşamba fan has been established from sediment cores and other geomorphological work. This outline includes the stratigraphic sequence, spatial distribution, and approximate extent of the major sedimentary units that comprise the fan. Inferences are also possible about past depositional environments and indirectly about the climatic and hydrological conditions prevailing at the time specific sedimentary units were formed (e.g. Roberts 1983). Unfortunately, attempts to develop a three dimensional lithostratigraphic reconstruction of alluvial sequences from sediment core data have shown that the local depth of alluvial deposits cannot be reliably modelled by means of simple interpolation of the data from core sample sites, although alluvial sediments are generally deeper towards the apex of the fan and shallower at its distal limits (Roberts 1996a: 2). A particular difficulty with regard to this type of reconstruction is that the upper surface of the Pleistocene lake marl has a complex and sub horizontal character, with outcroppings of lake bed marl at the surface of the fan in some localities (e.g. Driessen and de Meester 1969).

Several distinct land types can be identified within the Çarşamba fan study area. To the south of the Çarşamba fan, flat or undulating terraces are developed on Neogene limestone above the level of the former lake. At the edges of the basin, fossil beach ridges mark the former shoreline of the Konya palaeolake. The basin floor is a vast lacustrine plain, comprised of lake marls and calcareous soft lime soils that both surround and underlay the Çarşamba fan. The final land type is the alluvial plain of the Çarşamba itself, consisting of the alluvial deposits lain down by the river as it enters the basin, including the fine, clay-rich backswamps which extend towards the centre of the Konya plain (Roberts 1980: 187).





Scale  
 Kilometres  
 5 0

#### Key to soils units

1	Backswamp	5	Younger Backswamp
2	Fine Alluvium	6	Beach Ridge
3	Levee/Channel	7	Aeolian Clay Ridge
4	Sand Plain		

Figure 3.1 Map of soils units on the Çarsamba alluvial fan

Former beaches and shoreline deposits are found at the edges of the palaeolake and surrounding a series of secondary depressions on the bed of the former lake. The most substantial of these shoreline deposits is termed the Main Terrace, and lies at an elevation of  $1010 \pm 5$  metres a.s.l., a series of lower terraces at elevations below circa 1004 metres. These features have been identified to two groups on the basis of their different molluscan assemblages, the first representing shorelines formed at the time the entire basin was covered by the palaeolake, and the second group being formed more locally and discontinuously at a later date around a series of shallower and smaller isolated water bodies following the main fall in lake levels (de Meester 1971: 16). These smaller water bodies formed within five secondary depressions or component sub basins at Karapınar, Akgöl, Hamidiye, Hotamış and Yarma (Roberts 1983: 165-166).

The prominent sandy ridge to the north of Çumra, a beach spit of the palaeolake, was formed during the Pleistocene. This spit feature extends for approximately 15 kilometres east-west across the fan, terminating in an extensive sand plain, or playa, comprised of sediments deposited into the former lake by the May and Çarşamba rivers (Roberts 1980: 189). A series of radiocarbon dates from mollusc shells from the beach spit and other palaeolake shoreline deposits indicate that the last main fall in lake level took place *circa* 17,000 - 16,000 BP, i.e. 19 -18,000 calibrated BP (Roberts 1983: 159, Roberts et al 1996: 20). At some date after the main fall in lake levels, possibly under deglacial conditions at around 11,000 BP, the former beach spit to the north of Çumra was breached by the Çarşamba Çayı.

The lake bed marl is a fine-grained, carbonate-rich sediment deposited on the bed of palaeolake Konya and typically containing between 40-60 percent carbonate in the form of authigenic calcium carbonate precipitated from the former lake (Roberts et al 1996: 33-35). A thin band of dark organic clay locally overlying the marl in palaeochannel sections is probably a later marsh or shallow lake deposit, as indicated by its high clay and low sand content. A 'marsh marl' deposit identified in the Yarma secondary depression is believed to have formed during a short interval of lake re-advance during the terminal Pleistocene at around 12,000-11,000 radiocarbon yr. BP

(de Meester 1971: 37). This marsh marl unit may have a lateral equivalent in the vicinity of Çatalhöyük in the form of a thin layer of dark organic clay formed under lentic (standing water) conditions. The soft lime soils found in some areas of the former lake bed (Driessen and de Meester 1969) contain more than 60 per cent carbonate and are coeval with the lake marl, being formed where the palaeolake lay directly over Neogene limestone.

Alluvial fan deposits overlie the lake marl and organic clay deposits. The hydrological characteristics of the Çarşamba fan, have been described as more akin to a floodplain or delta than an alluvial fan, indeed de Meester suggests that the sediments to the north of the palaeoshoreline ridge be considered as a delta rather than as an alluvial fan (de Meester 1971: 10). The soils of the alluvial fan have a higher magnetic susceptibility than the underlying marls and dark organic clays, as a result of the presence of ferrimagnetic minerals from the Çarşamba catchment (Roberts et al 1996).

The surface of the Çarşamba alluvial fan is made up of sedimentary units of different age. Two main phases of post Neolithic alluvial sedimentation have been identified (Roberts 1980, Roberts 1982). The first phase consists of sediments lying below c. 1003m a.s.l. and is roughly equivalent to the Karkın soils series of Driessen and de Meester (1969). These sediments are characterised as heavy deltaic backswamp deposits which overlay white lacustrine marl to depths of between 1 and 4 metres. The older backswamps soils are considered to be of deltaic origin, in part because of the presence of planorbid shells which suggest they formed in a permanent (or near-permanent) water body.

The lower alluvium encountered beneath *in situ* Neolithic cultural deposits at Çatalhöyük, and linked to the Karkın soil series of Dreissen and de Meester (1969), has been OSL dated to around 8,000-9,000  $\pm$ 2,000 calendar years BP (Roberts et al 1996: 35). This range of dates and the stratigraphic relationship of the lower alluvium and the underlying dark organic clays, indicate that deposition of the lower alluvial unit in the vicinity of Çatalhöyük must have begun soon after the beginning of the

Holocene at around 11,000 calibrated BP. It is not known when deposition of the lower alluvium ceased, although fill deposits from a palaeochannel close to Çatalhöyük which postdate the lower alluvium and are sealed by the upper alluvial unit, date to the mid-Holocene at 7,000-4,500 Cal BP, indicating that formation of the lower unit must have occurred before this time.

The second and more recent phase of sedimentation is more varied, comprising levees, alluvial clays, silts and lighter backswamp deposits. The nature of these later deposits imply a seasonally rather than permanently inundated environment. These younger sediments continued to form throughout the Late Holocene, post *circa* 1000 B.C. (Roberts 1980: 189 and Roberts 1982: table 2). The upper alluvium reaches depths of between 1.5 to 2.5 metres in the vicinity of Çatalhöyük, while the total depth of post-Neolithic alluviation in the same area is around 3 metres.

The nature of the interface between the upper and lower alluvial units is of particular interest with regard to the reconstructing of the formation history of the fan. The clear contact recorded in cleaned section profiles in the vicinity of Çatalhöyük indicates that there was a break in deposition, or hiatus, between the formation of the lower and upper alluvial units. Roberts et al (1996) interpret this break as evidence of a period of stable conditions in the vicinity of Çatalhöyük, during which alluvial deposition may have been occurring elsewhere on the fan before renewed alluviation buried the old land surface (Roberts et al 1996: 36). The stratigraphic relationship of the upper alluvium and the lower alluvial unit and channel fill sediments indicates that the formation of the upper alluvium dates to the late Holocene (Roberts et al 1996).

The upper alluvium has both a higher carbonate content and higher magnetic susceptibility than the lower alluvium and contains a significant coarse fraction. These features suggest a contrast in the catchment area of the Çarşamba between the early and late Holocene (Roberts et al 1996: 36). The formation of the upper alluvium may also be linked to an increase in the frequency of overflows from the Beyşehir - Suğla basin, ultimately likely to have a climatic and/or anthropogenic

cause, for example as a consequence of increased surface run-off and enhanced soil erosion following Bronze Age and later deforestation of the Çarşamba upper catchment (Roberts et al 1996). While the formation of the younger backswamp soils and Çarşamba alluvium is dated to the interval post c. 1,000 BC (Roberts 1982: 346), i.e. after c. 3,000 BP, the deposition of this unit evidently ceases before occupation of the Roman and Byzantine settlement at Efreköy immediately north of the Çatalhöyük East mound.

The difficulties in directly dating the sedimentary units of the Konya basin are comprehensively reviewed by Roberts (1980). These include the fact that the fan sediments typically contain only sparse or derived organic material, making the application of radiocarbon dating methods and the derivation of precision dates difficult. The process of obtaining an accurate chronology for the formation of the fan is further complicated by the need to rely on shell carbonate as the main dateable material. A particular issue with shell carbonate is the possibility of contamination, either in the form of old carbon uptake from the underlying limestone and marl sediments, or in the form of younger carbon derived from the formation of secondary carbonate minerals (Roberts 1980: 108-113, Roberts 1983: 157-158). The decision to use Optically Stimulated Luminescence (OSL) methods to date sediment samples recovered as part of recent geoarchaeological work conducted at Çatalhöyük was intended to address this difficulty (Roberts et al 1996: 23).

Discontinuities recorded in sediment cores obtained within the Konya basin, and elsewhere across the desiccated lake basins of the eastern Mediterranean region, suggest that sediment sampling is unlikely to yield a full and unbroken record of Quaternary climate change (Roberts et al 1999: 498). Unfortunately, gaps in local sedimentary sequences tend to affect precisely that part of the palaeoclimate record that is potentially of greatest interest to archaeologists investigating the early settlement history of the Konya basin.

The analysis of a long sediment core obtained from a spring-fed pool beside the early prehistoric rock shelters at Pinarbaşı revealed a 'major hiatus' at the top of the core,

such that the upper sequence including the entire Holocene was missing (Reed et al 1999). The discovery of a similar hiatus at the top of a second long core extracted from the bed of the small (*circa* 1km diameter) saline-alkaline lake of Suleymanhaci gölü near Karadağ, is interpreted as evidence for an important arid interval occurring after the last glacial maximum, (Reed et al 1999: 640). A further long core from marsh sediments at the eastern end of Ak göl lake, near Adabag village, includes sediments dating to the terminal Pleistocene and early Holocene and suggests new plant resources and climatic amelioration several millennia before the earliest local archaeological evidence for proto-agriculture (Reed et al 1999).

A series of shell-dated sediments described by de Meester (1971) predate the Neolithic, but are important in establishing the limnological histories of the secondary depressions. *Lymnaea* shells from the dark organic marls overlying white lake marl in the Yarma depression have been dated to  $12,010 \pm 65$  BP and  $10,950 \pm 65$  radiocarbon yr BP (de Meester 1971: 31). The organic marls of the Yarma depression also contain a rich freshwater molluscan fauna, including freshwater planktonic diatoms and ostracods. This faunal assemblage is suggestive of a shallow open water body that would have been rich in vegetation and rather eutrophic in character (Roberts 1980: 163). The presence of collapsed worm casts in the upper metre of the white marl underlying the organic marl together with possible desiccation crack features in the same unit is interpreted by de Meester as evidence for seasonal flooding and desiccation of the Konya basin at the time the last white marl was formed (de Meester 1971: 70).

OSL age determinations are expressed directly in calendar years with an associated percentile error estimate. Error estimates for the Çatalhöyük palaeochannel samples vary between 16% and 25% (Roberts et al 1996: 24). The resulting age ranges for fills within one of the Çatalhöyük palaeochannels (PC1) bracket the interval from 7,000 BP to 4,500 calibrated BP, i.e. Chalcolithic through Early Bronze II periods. A mid-Holocene date for the abandonment of this channel would mean that it postdates the Neolithic occupation at Çatalhöyük. The well-defined transition between the upper and lower alluvium in the Çatalhöyük area, indicates a hiatus or break in



alluvial deposition between the formation of the two units. While the range of possible dates for the PC1 channel does not allow the beginning of the break in deposition between the upper and lower alluvium to be established closely, the upper alluvial unit postdates the PC1 channel, and is by inference of late Holocene age (Roberts et al 1996: 36).

Pottery recovered from channel fills near Çatalhöyük, may derive from the use of active or disused channels for the refuse disposal by the inhabitants of Çatalhöyük (Roberts et al 1996: 36-39), or from the reworking of tell material by natural processes in the millennia since the site was abandoned.

### 3.3 Hydrology

Alluvial fans are dynamic settings with the potential for high-amplitude environmental variability on a range of timescales. Sediment cores from the Çarşamba fan indicate a complex past hydrology, and Roberts et al (1996) observe that the hydro-geomorphological characteristics of this large alluvial fan resemble those of an alluvial floodplain (Roberts et al 1996: 19). An important feature of the past hydrology of the fan is that early and more recent phases of active alluvial deposition were apparently separated by a major period of hiatus.

The past flow regime of the Çarşamba Çayı is distinguished from those of the other rivers entering the western Konya basin because of evidence for periodic overflows from the Beyşehir-Suğla intermontane depression. These periodic overflows would be channelled via the Balıklıavı gorge into the upper Çarşamba catchment. Even if the Beyşehir-Suğla depression is excluded, the Çarşamba catchment is the largest of any river entering the Konya basin at 1720 square kilometres. This value is rather greater than that of the neighbouring May river, which enters the basin to the west of the Çarşamba, and has a catchment of around 1400 square kilometres (Roberts 1980).

Prior to regulation of the Lake Beyşehir outflow by the construction of a sluice in the early years of the twentieth century, and subsequently by the construction of the



Apa dam in 1962, the Çarşamba probably followed the seasonal flow regime typical of other rivers entering the Konya basin which are not spring-fed, i.e. with peak flow levels in the March - May period (Roberts 1980). Soils in the basin would have been generally waterlogged for much of the year (Roberts et al 1996: 19).

In most years, the discharge patterns for the Çarşamba and neighbouring May rivers would have been broadly comparable, with the volume of water carried by the May river perhaps three fourths that carried by the Çarşamba (the modern mean annual discharge of the two rivers is 73.4 and 94.0 million cubic metres respectively, Roberts 1980: 90). At those times when the Çarşamba was augmented by overflows from the Beyşehir-Suğla intermontane depression, it would draw upon a greatly increased (6780 sq. km.) catchment area. The volume of water carried by the two rivers would be very different under these conditions, with the increased discharge from the Çarşamba perhaps three times its present day mean annual flow, or around 332 million cubic metres per annum (Roberts 1980: 90). Overflows from the Beyşehir-Suğla catchment are believed to have taken place during the periods of lake transgression recorded in sedimentary sequences from the bed of Beyşehir Gölü, i.e. at around 21,000 BP, 11,000 BP and 4,000 BP.

Interannual variability in the flow of the Çarşamba also appears to have been high under natural conditions, as historical records attest to exceptional years of reduced flow. The course of the Çarşamba reportedly remained dry for much of 1846 - 1847 in the area around İçeri Çumra (Tchihatcheff 1853, cited in Roberts 1980). During the mid and late nineteenth century, a sequence of severe droughts affected the Konya basin, causing food shortages and the displacement of local populations in 1844, 1854, 1874 and 1878. In the period since the completion of the Konya irrigation project, exceptionally dry conditions that adversely affected crop yields were recorded in the Konya area in 1927-1928 and 1940 - 1941.

Against this background of recent periodic drought and even occasional failure of the seasonal flow regime of the Çarşamba, lake levels at Suğla Gölü also appear to have been highly variable. A nineteenth century visitor to the area was told that Suğla

dried up completely every ten or twelve years, and at these times the local people who fished the lake during 'normal' years would cultivate crops on the dried lake bed (Hamilton 1842, cited in Roberts 1980). A later visitor to the area records that this was the situation in 1903 (Huntington 1911: 99). The weight of evidence suggests that overflows from Suğla Gölü occurred very rarely, if at all in the century or so preceding the development of the modern irrigation system (Roberts 1980: 94-95).

An abandoned river channel mapped by Driessen and de Meester (1969) in the vicinity of the Hellenistic settlements of Kervan Hüyük and Koçatömek is unusual in that it is clearly visible on satellite imagery of the area. Fragments of other relic channel features are visible from satellite imagery as vegetation patterns or dark linear features under bare soil conditions in the vicinity of Pırsanlı Hüyük, Sırcalı Hüyük, Samıh Hüyük and Erminler Hüyük. A linear low-lying marshy area marked on the 1:25,000 scale topographic maps crossing the south-eastern fan between Sarlak Hüyük and Kuru Hüyük suggests the easterly continuation of another former channel.

Elsewhere in the fan, and particularly in the central and western fan, palaeochannel features are not generally visible at the surface, although mid-Holocene palaeochannels in the vicinity of Çatalhöyük were originally recognised as areas of darker soil in ploughed fields surrounding the East mound (possibly due to increased soil moisture retention above these features, as the underlying channel fill deposits are capped by more than a metre of later alluvial sediment). The fact that similar features are not observed elsewhere across the fan suggests that the course of the Çarşamba has remained relatively stable since the last major episode of overbank alluviation on the fan. In the central fan, oversize fossil meanders are visible cut into the shoreline ridge, east of the modern Çarşamba channel (Driessen and de Meester 1969). The size of these fossil meanders suggests that the bankful discharge of the Çarşamba at around the time the former shoreline spit was breached was considerably greater than at present (Roberts 1980: 189).

The area around Çatalhöyük was apparently free of permanent water cover throughout the climatic transition following the last glacial, although an extensive marsh or shallow lake may have lain to the north of the settlement, centred on the Yarma secondary depression (Roberts et al 1996: 20). Erol has proposed that a minor lake re-advance took place in the Konya basin during a mid-Holocene 'climatic-optimum' between approximately 7,000 - 5,000 BP (Erol 1978: 130), although this contradicts the chronology put forward by de Meester (1971) for the late Quaternary development of the Konya basin, which envisages progressive desiccation between 11,000 and 5,000 BP. Roberts notes that there have been important geomorphological and hydrological changes on the Çarşamba fan since c. 11,000 BP, '...in particular during mid-Holocene times, when there was more extensive flooding than at present and perhaps even the development of shallow lakes...' (Roberts 1982: 346).

The fill deposits recorded in the Çatalhöyük palaeochannels vary from fine silts to sediment-supported gravels, indicating considerable variability in past flow regimes. The fluvial sand and gravels in particular indicate relatively high-energy depositional environments within the river channel (Roberts et al 1996). Palaeochannel sections at Çatalhöyük are also found to have cut down through the fan alluvium into the underlying lake marl, presumably during a period of hiatus between the deposition of the lower and upper alluvial units. Following this period there is evidently a return to wetter conditions on the fan, as the younger backswamps and Çarşamba alluvium formed under conditions of periodic, perhaps seasonal, inundation of the plain during the late Holocene (Roberts 1982: Table 2).

It remains to be established whether Çatalhöyük was surrounded by alluvium during the Neolithic, although an original location near the outer edge of contemporary fan deposits appears probable (Roberts 1980: 233). The twin mounds at Çatalhöyük may have originally comprised a single settlement built on the slightly raised banks to either side of a central river channel. Analysis of the sediments beneath Çatalhöyük has shown that these are not classic *levée* deposits (Roberts et al. 1996: 39), although

a raised location of this sort would present an advantageous situation in the generally low-lying landscape of the fan (Roberts 1982: 346-347).

The recognition that significant alluvial deposits have been lain down in the vicinity of Çatalhöyük has implications for the earlier debate on the depth of cultural material recorded by Mellaart below the surrounding modern surface of the fan (e.g. Cohen 1970, French 1970a, Todd 1976). The discrepancy between the depth of post Neolithic alluvial sediments in the vicinity of Çatalhöyük and the depth of occupation debris reported by Mellaart is now recognised to be smaller than was originally assumed. The difference may be partly explained by the compression loading of natural sediments beneath the mound (Roberts 1982: 346, Roberts et al 1996: 37).

Geomorphological work has shown that information about modern soils and water resources cannot be used to assess past conditions during the Neolithic (Roberts 1982: 341, *contra* Cohen 1970), although the pattern of modern soils distributions may allow some inferences to be made about more recent past environments. While Neolithic land surfaces are buried beneath metres of later alluvium in the central fan, later land surfaces are less deeply buried. In situations close to the distal margins of the fan, only a thin veneer of alluvial material covers the underlying lake marl. Elsewhere, in areas that have not been subject to alluviation such as the Pleistocene shoreline ridges, the archaeological evidence for early settlement activity may lie at the modern soil surface.

### 3.4 Palaeoclimate

For the purpose of interpreting the archaeological evidence for past settlement distributions on the Çarşamba fan, the main concern is with Holocene climate, i.e. the interval since the end of the European Late Glacial and Younger Dryas cold event at *circa* 10,500 BP. Efforts have been made to reconstruct Holocene climatic conditions in the Konya basin from sediment cores at residual lakes, from the sediment sequences of the alluvial fans themselves, and dune formations and the

plant and faunal remains recovered by archaeological excavations. Various palaeoecological analyses have been applied within these diverse settings. Climatic conditions at the time of the transition between the late Pleistocene and early Holocene, and their significance in terms of the origins of agriculture, have been extensively debated in Near Eastern archaeology. Moore and Hillman (1992) for example have argued that the global cooling experienced during the Younger Dryas had a significant impact on the climate, vegetation and human economy of south-western Asia.

Two palynological indicators of past climatic conditions in the Near East and Levant are levels of arboreal pollen, and the presence of *Chenopodiaceae* and *Artemisia*. High levels of arboreal pollen (AP), generally oak pollen (*Quercus*) in the Levant and *Pinus* in Anatolia, are considered to be an indicator of increased precipitation (Wright 1993: 461). *Chenopodiaceae* and *Artemisia* are indicators of more arid or steppic conditions. El-Moslimany has also identified the ratio of *Poaceae* (grass or cereal) pollen to *Artemisia* and *Chenopod* pollen (P/A+C) as a key indicator of moisture conditions. The presence of high levels of *Poaceae* pollen when compared to modern samples is a feature of early Holocene pollen assemblages in the Middle East (El-Mosimany 1994: 121-125). Important individual palynological sequences for the reconstruction of wider regional palaeoclimates in the eastern Mediterranean at the transition from the Late Glacial to Early Holocene period have been obtained from the Ghab valley of the Orontes River in north-western Syria, from Huleh in the Jordan Valley and from Abu Hureyra on the Euphrates.

Baruch and Bottema (1991) describe a 17-metre sediment core from the Huleh area, which provides pollen sequences for the Late Glacial to Early Holocene period. The lower six metres of Baruch and Bottema's core are interpreted to represent the period 17,000 - 9,000 BP, based on a series of four radiocarbon dates obtained on sediment samples taken at intervals from this part of the core. Consideration of the relative proportions of arboreal and grass pollen are used to infer aridity. The early part of this core, dating to the period before the beginning of the Late Glacial (*circa* 14,000 BP) displays low arboreal pollen (AP) values, suggesting conditions in the Huleh

area at this time would have been drier and cooler than at present (Baruch 1994: 105).

The pollen evidence from Huleh shows AP values increasing to around 30% at the beginning of the Late Glacial, from around 10% in the preceding Pleniglacial period. Throughout the first half of the Late Glacial, AP values continue to increase, reaching a maximum of around 75% around 11,500 BP. A sharp decrease in AP values during the period 11,500 - 10,500 BP suggests deterioration in climate, although the absolute size of any decrease in precipitation may have been relatively small in view of the relatively high temperatures prevailing before the onset of the Younger Dryas. Forest cover continues to decline during the cooler conditions of the Younger Dryas, suggesting a significant reduction in precipitation levels at this time. In the period immediately before the beginning of the Holocene, the climate of the southern Levant may have been almost as unfavourable as during the Pleniglacial maximum (Baruch 1994: 110). An increase in relative humidity appears to take place at the beginning of the Holocene, when rising levels of arboreal pollen indicate a re-expansion of forest at a time when global temperatures were also increasing.

The sequence from Ghab shows marked fluctuation in AP/NAP (Arboreal/Non Arboreal pollen - principally *Artemisia* and *Chenopod*) ratios during the Pleniglacial, suggesting considerable shifts in forest versus steppe vegetation covers. These shifts are interpreted as evidence for significant fluctuations in temperature and precipitation conditions (van Zeist and Woldring 1980). During the interval *circa* 14,000 - 11,000 BP, AP levels decrease to 10%, their lowest value throughout the entire sequence. This minima is followed by a large increase in AP levels to reach a maximum of around 60%. After 11,000 BP, there is evidence for forest re-expansion, interpreted as being triggered by the global decline in temperature during the Younger Dryas, resulting in changed runoff/evaporation ratios and possibly accompanied by an increase in absolute precipitation levels. The continued expansion of forest at the onset of the Holocene despite a renewed rise in global temperatures is interpreted as evidence for a further increase in precipitation levels at this time (Baruch 1994).



Unfortunately the poor chronological control of the Ghab pollen diagram prevents detailed comparison with the features of the Huleh sequence of Baruch and Bottema (Baruch 1994). The dating of the Huleh sequence would appear to be the most secure of the two, having a series of four radiocarbon dates distributed over the length of the core, compared to the single date of the Ghab sequence (van Zeist and Woldring 1980). Wright (1993) notes that improved dating resolution at the Late Glacial - Early Holocene transition may be difficult to achieve using radiocarbon methods, because of the presence of 'plateaus' in the calibration curve, centred on 12,500, 10,000 and 9,500 years BP (Wright 1993: 463). Moore and Hillman (1992) similarly comment that the comparison and interpretation of existing radiocarbon dated sequences should allow for the possible presence of systematic variations in dating of up to some hundred of years (Moore and Hillman 1992: 489).

There is some evidence from Near Eastern lake records to support a division of the region into northern and southern zones that may have experienced differing palaeoclimatic conditions (Roberts 1980: 252-257, Roberts 1983: 168). Considerable spatial inhomogeneity is found in the modern climate of the Eastern Mediterranean / Levant region, and this may have been the case under past conditions (Roberts 1983, El-Moslimany 1994, Baruch 1994). The presence of quercus pollen throughout the Ghab sequence is interpreted by El-Moslimany as an indication that this area was more susceptible to incursions of summer rainfall during the Early Holocene than other more continental sites. Baruch (1994) comments that the differences observed in the pollen sequences at Ghab and Huleh may be an artifact of dating error between the two sites.

Alternatively, the climatic regime in the Levant during the Pleistocene and Early Holocene may have been divided into northern and southern provinces having diachronic climate histories (Baruch 1994: 110-111). Patterns of forest expansion throughout the Near East indicate that the climatic amelioration apparent in the southern Levant during the Late Glacial at 12,000 - 11,000 BP may have shifted to more northerly areas over a period of some millennia, with similar conditions



appearing as late as 8,000 - 7,000 BP in south-central and south western Anatolia (Baruch 1994: 118-119).

The multi-proxy analysis of varve records from Lake Van in eastern Turkey has provided a continuous palaeoclimatic record with annual resolution and a time depth of  $14,720 \pm 426$  varve years (Lemke et al 1997). The analysis of variations in the  $\delta^{18}\text{O}$  content of lake sediment carbonates in the annually laminated lake bed sediments of Lake Van in eastern Turkey suggest that between 4,200 and 2,100 BP (varve years), climatic conditions were much more arid than at present (i.e. since 2,100 BP). An earlier arid phase is also identified between 11,550 - 10,460 BP, while between 8,190 - 4,200 BP, conditions became more humid. Conditions in the period 10,460 - 8,190 BP, were similar to those of today. Mg/Ca and Sr/Ca ratios are also used as an indicator of changing salinity and to infer past lake levels (Lemke et al 1997). A Holocene climatic optimum is identified between ca. 6,000 - 4,000 years BP, with evidence in the pollen record for the continuous spread of *Quercus* woodland after 9,000 BP to reach its maximum expansion at the beginning of the Holocene climatic optimum.

A further implication of the varve sequence analyses at Lake Van is the very rapid transition in climate observed at the end of the Younger Dryas. The analysis of pollen, Mg / Ca ratio and  $\delta^{18}\text{O}$  values indicate that the transition from the extremely aridity and cool conditions which prevailed between 11,550 and 10,460 BP to conditions similar to those of the present day was completed within a space of between 10 and 50 years (Lemke et al 1997).

Wick et al (1997) report on pollen analyses carried out on core Van 90-4 obtained at a location near the centre of the lake. This analysis involved the sampling of the entire core at intervals to provide an overview of vegetation history with a dating resolution of around 130 varve years. The section of the core covering the Late Glacial / Holocene transition between 10,750 and 8,500 years was selected for a more detailed analysis and was continuously sampled. Each centimetre this section of the core contained approximately 18 annual varve deposits (Wick et al 1997).

Comparison of the reconstructed vegetation patterns for the Lake Van area derived from the pollen analysis with the parallel Mg / Ca ratio and  $\delta^{18}\text{O}$  record, has produced additional information which is of direct significance to the reconstruction of past climate conditions from key pollen indicators. The palynological record reveals a lag in vegetation response of about 400 years after the onset of drier conditions at 12,000 BP, and the presence of a further two-stage vegetational response lasting around 300 years following the transition to more humid climatic conditions at 10,460 BP. The first phase of the vegetation response contemporaneous with the change to more humid conditions after 10,460 BP consisted of increases in *Graminae*, *Pistacia* and *Quercus* and a decrease in *Artemesia*, accompanied by increases in fresh water demanding plants including *Populus*, *Vitis*, *Tamarix* and *Datisca*. The second phase of the vegetational response featured further increases in *Graminae* and *Pistacia* with decreases in *Chenopodiaceae* and *Ephedra*, the vegetational system becoming stable by *circa* 10,000 BP, i.e. more than four centuries after the climatic transition appears in the Mg / Ca ratio and  $\delta^{18}\text{O}$  records (Wick et al 1997).

The vegetation response times demonstrated for the Lake Van area are potentially important in assessing the impact of climate change on contemporary human populations and in the interpretation of the timing of events observed in the palynological record at other sites. With regard to the lag in vegetation response observed in the reconstructed Van vegetation sequence following the transition to more arid conditions at 12,000 BP, El-Moslimany (1994) has observed that deciduous oak forest may persist at favourable sites in summer-dry climates under conditions of low disturbance (El-Moslimany 1994: 127).

The synchronisation of changes in climatic conditions is suggested by the good qualitative agreement found between aridity in the Lake Van varve record, cool climate conditions in Europe and carbon 14 maxima, indicating periods of low solar activity. This tends to support the view that variations in solar activity may trigger synchronous changes in terrestrial climate (Lemke et al 1997). However, Roberts

cautions against assuming a simple relationship between glaciation and Near Eastern lake levels, pointing out that the dramatic and permanent drop in lake levels in the Konya basin at ca. 17,000 BP occurs well before the northward retreat of the ice sheets in North America and Fennoscandia.

After ca. 7,000 BP, further important environmental changes took place within the hydrology of the Çarşamba fan-delta. There is evidence for more extensive flooding of the fan during the mid-Holocene than under modern conditions. Also there is a two-phase alluviation, interspersed by a break or hiatus. Changed sedimentation regimes after 7,000 BP may have had climatic and or anthropogenic origins. Fluvial sands and gravels indicate high-energy depositional environments within the former river channels that flowed between the two mounds at Çatalhöyük in the mid Holocene and possibly in earlier periods. A link has been proposed between the increase in late Holocene sedimentation rates and enhanced topsoil erosion caused by anthropogenic modification of the Çarşamba catchment, perhaps by deforestation during the Bronze Age and later periods (Roberts et al 1996: 36).

Pollen sequences more local to the Konya basin have been obtained at Akgöl, a small lake within the basin (Bottema and Woldring 1987) and from Beyşehir gölü to the west (van Zeist et al 1975, Bottema and Woldring 1986). In addition to these long sequences, de Meester (1971) has analysed pollen from the upper white marl in the Konya basin. The upper marl pollen assemblage reported by de Meester is dominated by NA species, largely by Chenopods and *Tamarix*, although pollen from tree species is present, mainly *Pinus* (10%) with small quantities of *Quercus* (0.2%) and *Abies/Cedrus* (de Meester 1971: 18). The character of this assemblage suggests a steppe-like vegetation cover at the time the palaeolake was retreating by around 17,000 BP.

The base of the Ak göl pollen diagram published by Bottema and Woldring (1986) is dated to *circa* 13,000 BP. The lower end of this sequence is alternately dominated by *Artemisia* and Chenopods, suggesting desert and steppe vegetation in the vicinity of the former lake during the Late Glacial, with evidence for sparse growth of pine and

deciduous oak on hillsides surrounding the Konya basin. Baruch (1994) infers from this evidence that Late Glacial climatic conditions in the Konya basin were probably much drier than at present (Baruch 1994: 113). Towards the end of the Late Glacial a reduction in *Artemisia* values is accompanied by parallel rise in *Gramineae* and a slight increase in deciduous oak, indicating more humid conditions. An increase in *Betula* at a point in the core corresponding to the Younger Dryas, is followed by a subsequent early Holocene reduction in the amount of *Betula* pollen and increase in the level of deciduous oak to a maximum.

By *circa* 8,000 BP or later, *Pinus* and *Cedrus* increase rapidly in the Ak göl core, suggesting the replacement of deciduous oak by coniferous forest, an indication of higher precipitation levels around this time (Bottema and Woldring 1986). The low levels of summer precipitation indicators in the Ak göl core prior to *circa* 12,500 BP is interpreted by El-Moslimany (1994) as evidence that summer aridity in the Konya basin at this time was similar to that experienced at more continental sites. After 12,500 BP, the vigorous response of these summer precipitation indicators is controversially interpreted by El-Moslimany as evidence of summer precipitation in the Konya basin, as at Ghab in north western Syria.

The base of the Beyşehir II sequence (Bottema and Woldring 1986) has been radiocarbon dated to *circa* 15,400 BP. Zone 1 of the sequence, equating to the end of the Pleniglacial and early stages of the Late Glacial, contains low levels of AP (between 10% - 20% maximum), indicating arid conditions. Zone 2 of the Beyşehir II diagram is estimated to date to the period 12,300 - 10,900 BP, approximately corresponding to the Allerød interstadial of north-western Europe. This zone of the Beyşehir diagram shows higher AP values, dominated by *Pinus*, indicating that rising temperatures were accompanied locally by an increase in annual precipitation (Baruch 1994: 114). The marked decline in *Pinus* and of total AP values after this point are interpreted as a consequence of reduced temperatures during the Younger Dryas.

Levels of AP increase again after this point in the sequence, probably at the beginning of the Holocene, and include *Pinus*, *Cedrus* and *Quercus*. Baruch (1994) interprets this as evidence for the expansion of coniferous forest on hillsides south and west of Lake Beyşehir and of mixed broad-leaved woodland to the north and east, i.e. in the direction of the Konya basin. As temperatures continue to rise during the early Holocene, further increases in AP suggest that this trend towards higher temperatures was accompanied by greater humidity. Peak AP values occur in the Beyşehir II sequence at *circa* 6,000 BP uncalibrated, although humidity appears to continue to increase after this point, as *Quercus* pollen decreases to very low levels while that of *Pinus* increases at the expense of *Cedrus* (Baruch 1994).

It is difficult to observe clear climatic patterns in the pollen record from this area for the period 4000 BP to present because of the impact of human activities on vegetation succession (Bottema et al 1993). However, Bottema et al (1993) argue that the rapid spread of the suite of plant species collectively recognised as the Beyşehir Occupation phase, and the apparent expansion of forest into formerly steppic areas indicated in the pollen record, could not have occurred under the disastrous drought conditions proposed by some authors at the end of the Bronze Age, *circa* 1200 BC (e.g. Klengel 1974, Betancourt 1976, Otten 1983, Shrimpton 1987).

The key features of the Beyşehir Occupation phase (van Zeist et al 1975, Bottema and Woldring 1984, 1986, 1990) are an increase in *Olea* pollen and the pollen of other cultigens including *Juglans regia*, *Castanea sativa*, *Fraxinus ornus* and *Platanus orientalis*. There is also the appearance of weed species associated with cleared and cultivated landscapes. This period is also marked by the rapid decline of natural forest components and their replacement by cultivated tree species.

The Beyşehir Occupation phase is interpreted as resulting from the exploitation of orchards and increased grazing pressure against a background of increasing moisture conditions (Bottema et al 1993). The dating of the Beyşehir Occupation phase varies in different locations, but its onset is generally dated to 3200 B.P. or around 1500 BC calibrated (Bottema et al 1993: 62). Similarly, this characteristic increase in

anthropogenic species is not manifested equally strongly in all pollen diagrams. The type site for the Late Holocene and Beyşehir Occupation phase is the Beyşehir I pollen diagram of van Zeist et al (1975).

### 3.5 Late Glacial and Holocene palaeoenvironments of the western Konya basin

Attempts at the detailed reconstruction of Holocene palaeoenvironments in the Konya basin have encountered problems of adequate chronological control and breaks in the sedimentary record. Efforts to obtain a continuous local sediment core sequence spanning the Holocene have so far been unsuccessful. The presence of a hiatus or break between the formation of the upper and lower alluvial units on the fan is particularly problematic with respect to reconstructing environmental conditions during the mid-late Holocene. Sediments within the basin are difficult to date using radiocarbon methods, because of problems with carbon uptake and the presence of only sparse or derived material suitable for dating. The age of major sedimentary units on the Çarşamba fan and the timing and duration of Holocene formation processes remain to be determined with sufficient accuracy to allow the reconstruction of physical environments conspecific with archaeological settlement distributions. Despite these difficulties, an outline palaeoenvironmental history can be constructed for the study area from the available evidence.

An important date with regard to the investigation of past settlement patterns within the Konya basin, is the date at which the floor of the Konya basin would have first become accessible to human groups following the recession of palaeolake Konya. Radiocarbon dating of the fossil shorelines associated with the last major lacustral phase during which the basin was covered by a large single body of water, indicate that the main drop in lake levels took place during the Pleistocene at around 17,000 BP (Roberts et al 1979). This date, long before the earliest archaeological evidence for settlement so far recovered, provides a baseline for the reconstruction of the settlement history of within the Konya basin. Pollen assemblages obtained from the upper marl sediments left by the retreating lake by de Meester (1971) suggest that the



environment of the Konya basin would have been steppic at the time of the last major decrease in lake levels.

The Yarma-Hotamış depression is believed to have dried out during the interval *circa* 17,000-12,500 BP, an indication that the remainder of the basin floor would have been dry at this time resulting in a Late Pleistocene gap in the sedimentary record of the western Konya basin (Roberts 1983: 165). Sediment cores from the secondary depressions closest to the Çarşamba fan indicate the presence of a small marshy lake at Hotamış after 12,500 BP, while the Yarma depression to the north contained a marsh. The Hotamış and Yarma depressions were connected by a series of channels in this period (de Meester 1971: 37). Traces of former channels linking the two areas are visible on Landsat TM imagery of the area and are mapped by de Meester et al (1969), presumably from aerial photographs.

Radiocarbon determinations carried out on freshwater mollusc shells from Yarma have dated the formation of the Yarma - Hotamış secondary lakes to a period of climatic amelioration occurring at around 12,000-11,000 BP (de Meester 1971, Roberts 1983: 167). El-Moslimany (1984) suggests that the Konya basin may have received significant summer rainfall from *circa* 12,500 BP, based on the pollen evidence from Ak göl and Beyşehir Gölü. Other secondary depressions within the Konya basin also held shallow water bodies during this lacustral phase (Roberts 1980, Roberts 1983).

The Çarşamba breaks through the former shoreline spit north of Çumra at an early date, most probably under deglacial conditions *circa* 11,000 BP (Roberts 1980: 212-213). The formation of two palaeomeander features, cut into the shoreline spit east of the point where it is breached by the Çarşamba and mapped by de Meester et al (1969), may also date to this time, indicating that peak discharge levels of the Çarşamba would have been much higher than under modern (i.e. pre-1900) conditions. It is likely that the Çarşamba was receiving high volume overflows from the Beyşehir-Suğla catchment at the time the shoreline spit was breached (Roberts 1980: 213).



Between *circa* 11,000 and 7,000 BP, there is evidence for a trend towards increased aridity within the Konya basin. On the neighbouring Ibrala fan near Karaman, Roberts (1991) notes on the transition from coarse and/or poorly sorted lower alluvial deposits laid down prior to the founding of the Neolithic settlement at Can Hasan III, to the deposition of fine grained, moderately sorted alluvial deposits in the Holocene. This change in the character of the material being deposited would imply a change in the alluvial regime of the Ibrala between the Late Glacial and Early Holocene.

Elsewhere within the Konya basin, the isolated lakes formed within secondary depressions on the floor of the basin are replaced by marshes and playas, and ultimately by steppe (Roberts 1980: 229-232). The truncation of long sediment cores from the small residual water bodies at Suleymanhaçi gölü and Pinarbaşı in the Konya basin indicate a hiatus in the sedimentary record linked to an arid interval at some stage after the Late Glacial Maximum (Reed et al 1999: 640). Evidence for increasingly arid conditions is also found in dune formations at Karapınar in the northern Konya basin (Erinç 1962). The period of maximum aridity in the Konya basin appears to date to around 7,000 BP (Roberts 1980).

During the mid Holocene after *circa* 7,000 BP, there is evidence for a period of increased flooding on the Çarşamba fan (Roberts 1983: 346). The palynological record indicates increased humidity at around this time. Elevated AP values in the Beyşehir II sequence occur at *circa* 6,000 BP and there is evidence for the continued improvement of moisture conditions after this time (Baruch 1994: 114). The varve record from Lake Van suggests that climatic conditions may have become more humid across the region during the mid-Holocene, with multi-proxy environmental pollen and lake chemistry indicators indicating a 'climatic optimum' between *circa* 6,000 - 4000 varve years BP, followed by a return to more arid conditions in the interval *circa* 4,200 to 2,100 varve years BP (Lemke et al 1997).

On the Çarşamba fan, the formation of the lower alluvial unit at Çatalhöyük, linked the Karkın soil series of de Meester et al (1969), is followed by a period of hiatus and

then by the formation of the upper alluvial unit through renewed overbank sedimentation during the mid-late Holocene, most probably commencing in the period since *circa* 3,000 BC. The human modification of landscapes within the catchment of the Çarşamba, leading to increased run off and soil erosion, may be implicated in the onset of renewed alluviation on the fan at this time (Roberts et al 1996).

The palynological record throughout the region becomes less informative as an indicator of palaeoclimatic conditions from *circa* 4,000 BP because the anthropogenic modification of natural vegetation covers dominates the pollen record from around this time (e.g. Bottema et al 1975). Key palynological indicators infer an improvement in moisture conditions in south western Anatolia during the 'Beyşehir Occupation phase', between 3,200 and 2,000 BP uncalibrated (Bottema and Woldring 1990) i.e. *circa* 3,400 to 2,200 BP calibrated (Baruch 1994: 117). This improvement in moisture conditions continues for a short period beyond the end of the Beyşehir Occupation phase but is followed by a return to drier conditions across the region by around AD 400 (Bottema and Woldring 1986).

## **Chapter 4: Past Settlement On The Çarşamba Alluvial Fan.**

### **4.1 Introduction.**

This section describes reconstructed past settlement distributions for the Çarsamba fan. These reconstructions are largely based on the preliminary results of the Çatalhöyük Regional Survey project, directed by Dr. Douglas Baird of the University of Liverpool (Watkins and Baird 1994, Baird 1996a, Baird 1996b, Baird 1997), with additional information from previously published archaeological surveys (Mellaart 1955, Mellaart 1958, Mellaart 1961, Mellaart 1963a, French 1966, French 1970).

The reconstructed settlement distributions described in this chapter draw on the most current information available at the time of writing, frequently on first observations made at the time of survey and during the initial stages of finds processing. The ongoing detailed specialist analysis of the surface collected material summarised here is expected to result in the future refinement of the reconstructed occupation histories at many of the locations discussed, indeed this is a major objective of such work. The procedures used in the archaeological survey of past settlement sites are now described.

### **4.2 Survey methodology.**

The systematic and intensive archaeological field recording carried out by the Çatalhöyük Regional Survey project in the western Konya basin has emphasised the survey of known sites and the investigation of locations identified as potential sites through the inspection of topography and using remote sensing methods. At the time of writing, this project has recorded over 120 past settlement sites and 300 individual occupation phases, representing a huge quantity of new information on the settlement history of the Çarşamba fan.

The methodology employed by the Çatalhöyük Regional Survey has been set out in detail elsewhere by the director of the project (Baird 1996a), but some key features

may usefully be described here. Contour mapping has been carried out at most sites as a part of the survey process together with a systematic surface collection. An important element is the organisation of surface sampling using into 3 x 3 metre collection squares across the site (Baird 1996a: 44-45). Each collection square is lightly scraped using a shovel and the resulting soil dry-sieved through 8mm mesh. Archaeological materials are recovered and identified to the square in which they were found.

Shovel scraping to depths of < 5 cm has been identified as an effective technique for the recovery of minor components from a surface-collected sample (Kirkby and Kirkby 1976: 246 Table 5). The dry-sieving of material from surface collection squares serves to standardise the level of recovery from survey squares and to increase the recovery of unobtrusive materials (Baird 1996a: 45). A conventional general surface collection (i.e. a purposive or 'grab' sample) is made separately at each site.

A programme of off-site survey in the form of the field-walking of harvested crop fields and irrigation and drainage canals has also been conducted as part of the Çatalhöyük Regional Survey fieldwork (Baird 1996a: 42-44). The field-walking of irrigation or drainage canals has long been recognised as a useful technique in semi-arid areas (e.g. Kirkby and Kirkby 1976: 241, Wilkinson 1990: 49). The unlined canals of the Çarşamba fan are substantial features, excavated through the full depth of the alluvial deposits and into the underlying Pleistocene lake marl. These earth-cut canals, and the associated mounds of up-cast material produced along their length by annual cleaning, provide convenient linear transects with good ground visibility and create conditions in which buried archaeological material is likely to be brought to the surface. Unfortunately the construction of concrete-lined canals and sectional prefabricated irrigation channels since the mid 1990s has led to the progressive abandonment of earth-cut canals.

Probabilistic sampling has sometimes been considered of limited value in the detection of rare or highly clustered archaeological features, particularly where these

features are also of small size (e.g. Flannery 1976: 135, although see Binford 1964). The frequency of sites revealed in the sides and raised banks of canals and similar exposures may however offer some basis for the estimation of background site density where visibility conditions are otherwise poor (Schiffer et al 1978: 7). With respect to background site density estimates on the Çarşamba fan however, it is apparent that the distribution of irrigation canals is not random. Canals follow low-lying routes across the landscape, and there is evidence that at least some are in close proximity to the courses of former natural stream channels (e.g. Driessen and de Meester 1969: 98). The programme of walking has therefore been extended to open areas of the fan away from the canal network.

The walking of canals and areas of open cultivated fields under conditions of good ground visibility, has demonstrated that extensive areas of the modern fan surface contain no visible settlement remains. This observation supports the view that past settlement sites occur in this setting as discrete features that occupy a small proportion of the total area of the fan, and are separated by archaeologically sterile land surfaces. There is no low-density background scatter of archaeological material, as has been found in some settings (e.g. Lock et al 1999, Wilkinson 1990), despite evidence for intensive settlement activity over several millennia. This localised distribution of archaeological materials at discrete sites is the product of long-term alluviation leading to the burial of ancient land surfaces beneath more recent sediments.

Settlement distributions reconstructed from surface survey evidence can obviously include only those settlements that have been identified and mapped and may, for several reasons, not be a full or accurate picture of actual settlement distributions. In terms of the completeness of the information used to reconstruct past settlement patterns, it is apparent that there is potential for the under-representation of settlement activity in some periods and in some areas. The bias introduced by differential recovery factors is likely to be significant in an alluvial landscape like the Çarşamba fan. While the largest multi-period mounds are highly obtrusive, often visible from several kilometres away, and the complete or near complete recovery of

such sites is anticipated, the recovery of smaller settlements is likely to vary according to local visibility conditions.

At the level of the individual site, the recovery of less obtrusive components within a surface artifact assemblage may be less reliable at large settlement mounds, where the intensity of surface sampling effort is necessarily reduced because of the larger area of the site. Patterns of modern land use are also an important factor affecting the visibility of archaeological material. In the cultivated areas that cover much of the Çarşamba fan, ground visibility can vary throughout the agricultural year from the bare soil of harvested and newly ploughed fields, through semi-natural fallow field covers to complete ground covers of growing crops. Archaeological field survey generally takes place in August and September, in the period after cereal crops have been harvested and when the remaining stubble has been burnt. However, even at this time extensive areas of the fan remain under later maturing crops such as sugar beet, and are effectively inaccessible for the purpose of archaeological survey. Under these conditions it may be possible to survey these areas in a subsequent field season, after the harvest of an earlier maturing crop. Alternatively, remote sensing can increase the visibility and recovery of past settlement evidence, as discussed in chapter 7.

With any surface collected sample, there is the possibility that evidence from some occupation periods will not be recovered (French 1970: 139). Field experiments in the use of different collection techniques at multi-period sites have shown that surface collected samples are affected by choice of sampling methodology (Baker C.M. 1987, Watkins and Baird 1994). In particular, where reliance is placed on the judgmental 'grab sampling' of diagnostic materials, minor and less obtrusive components in a site surface assemblage, including evidence of early occupation activity, are likely to be missed (McManamon 1984: 227). The archaeological mound surveys carried out on the Çarşamba fan during the 1950s and 1960s were made by individuals or small groups, often under conditions that precluded intensive systematic sampling (e.g. Mellaart 1955: 311). It is therefore not surprising that evidence has subsequently been found at many mounds for occupation activity beyond that recorded in earlier surveys (e.g. Watkins and Baird 1994, Baird 1996a:



42). The archaeological evidence for past settlement distributions on the Çarşamba alluvial fan is now reviewed.

### 4.3 Past settlement distributions on the Çarşamba fan.

#### 4.3.1. The early prehistoric period.

The early prehistoric material found at Kızıl Hüyük I and Seyithan Hüyük (Baird 1997) and during preliminary excavations at Pinarbaşı at the southern end of Hotamış Gölü (Watkins 1996), is direct archaeological evidence for the presence of human groups in the western Konya Basin before 8,000 BC calibrated. The relatively small number of early prehistoric settlements so far recognised may be partly due to the limited range and unobtrusive nature of the physical evidence available. For periods before the development of ceramic technology, diagnostic cultural material is effectively restricted to chipped-stone tools and debitage that are easily overlooked during surface collection, even where intensive sampling methodologies are used. A further factor in locating early prehistoric settlement activity in the context of the Çarşamba fan is the considerable depth of later alluvial sediment that covers early prehistoric land surfaces.

While the earliest phases of human settlement on the Çarşamba fan cannot be reliably reconstructed on the basis of the evidence presently available, the presence of diagnostic chipped-stone artifacts at locations in the central and northern fan indicate that human exploitation of the Konya basin predates the Neolithic. This picture of early settlement of the basin floor is consistent with the geomorphological evidence for a final drop in the level of the Pleistocene Konya palaeolake several millennia before the earliest occupation at Çatalhöyük. Evidence for early prehistoric settlement close to the centre of the Konya basin long before the Neolithic also contradicts theories linking the establishment of Çatalhöyük to the exploitation of fertile soils newly-uncovered by the recession of Palaeolake Konya (e.g. Cohen 1970, Sherratt 1972).



#### 4.3.2. The Neolithic period.

The most prominent Neolithic settlement within the study area is the large hüyük at Çatalhöyük East, located near the centre of the modern Çarşamba fan, but perhaps closer to the outer edge of the fan as it existed in the Neolithic period (Roberts 1982: 346). The settlement mounds at Çatalhöyük are the only settlements of any period so far excavated on the Çarşamba fan, being originally dug by Mellaart between 1961 and 1965 (Mellaart 1967) and since 1993 by an international team directed by Prof. Ian Hodder (Hodder 1996).

The singular size of the Neolithic mound at Çatalhöyük East, at 15 hectares in area and 22 metres in height, and its spectacular material culture as revealed by excavation suggest that Çatalhöyük was a high status settlement and probable regional centre for contemporary populations. The archaeological evidence for Neolithic settlement activity within the Çarşamba fan study area is however not limited to the settlement at Çatalhöyük East but may also include materials from Kızıl Hüyük I, Seyithan , Sancak Tömek and possibly at Ali Hüyük Tepe.

Geomorphological investigations on the Çarşamba fan have revealed a sequence of changing environmental conditions since circa 6,000 BC calibrated which have caused Neolithic land surfaces to become buried across most of the study area (Erol 1978, Roberts 1982). The apparent distribution of Neolithic settlement activity based on the evidence from multi-period mounds must therefore be weighed against the knowledge that most contemporary land surfaces are deeply buried by later sediments, particularly in areas near the centre of the Çarşamba fan. Preliminary geoarchaeological investigations made as part of the KOPAL programme have established the depth of post-Neolithic alluvial sediment at around 2-3 metres in the vicinity of Çatalhöyük (Roberts et al. 1997: 37-39). The limited visibility and accessibility of Neolithic land surfaces at Çatalhöyük and elsewhere on the fan must therefore be considered in any interpretation of the observed pattern of Neolithic settlement activity.

While it is unrealistic to attempt a reconstruction of Neolithic population distributions on the Çarşamba fan on the basis of the limited information available, some features can be identified. Çatalhöyük East is clearly the largest local, and probably regional, settlement in this period. The view that Çatalhöyük was some form of 'centre' is often stated (e.g. Mellaart 1961, Bartel 1972, Todd 1976, Roberts 1980, Baird 1997).

A more detailed understanding of the functioning of Çatalhöyük East with respect to surrounding contemporary settlements has yet to emerge. The archaeological evidence for smaller Neolithic settlements within a few kilometres of Çatalhöyük (Baird 1996, Baird 1997) adds to the complexity of the reconstructed Neolithic settlement distribution. Although the size of Çatalhöyük East remains unique, it is evidently not the only Neolithic settlement on the Çarşamba fan as was once supposed (e.g. Cohen 1970, French 1970b, Sherratt 1972). The origins of the disparity in size between Çatalhöyük and its neighbours remain to be established.

#### 4.3.3. The Early Chalcolithic period.

The mapped settlement distribution for the Early Chalcolithic period has the form of an arc, open to the south and enclosing an apparently unoccupied central region north of the palaeoshoreline ridge between Seyithan and Sarlak Hüyük (Figure 4.1). Settlement in the Early Chalcolithic appears less extensive than in later periods and is concentrated towards the centre and east of the modern fan. The relatively wide spacing of the small, single period Early Chalcolithic settlements at Mezarlik II and Kuşlu Hüyük II may relate to the presence of the main channel of the Çarşamba, which passes between the two under modern conditions. The footprint of the modern village of Karkın may also obscure settlement evidence in this area.

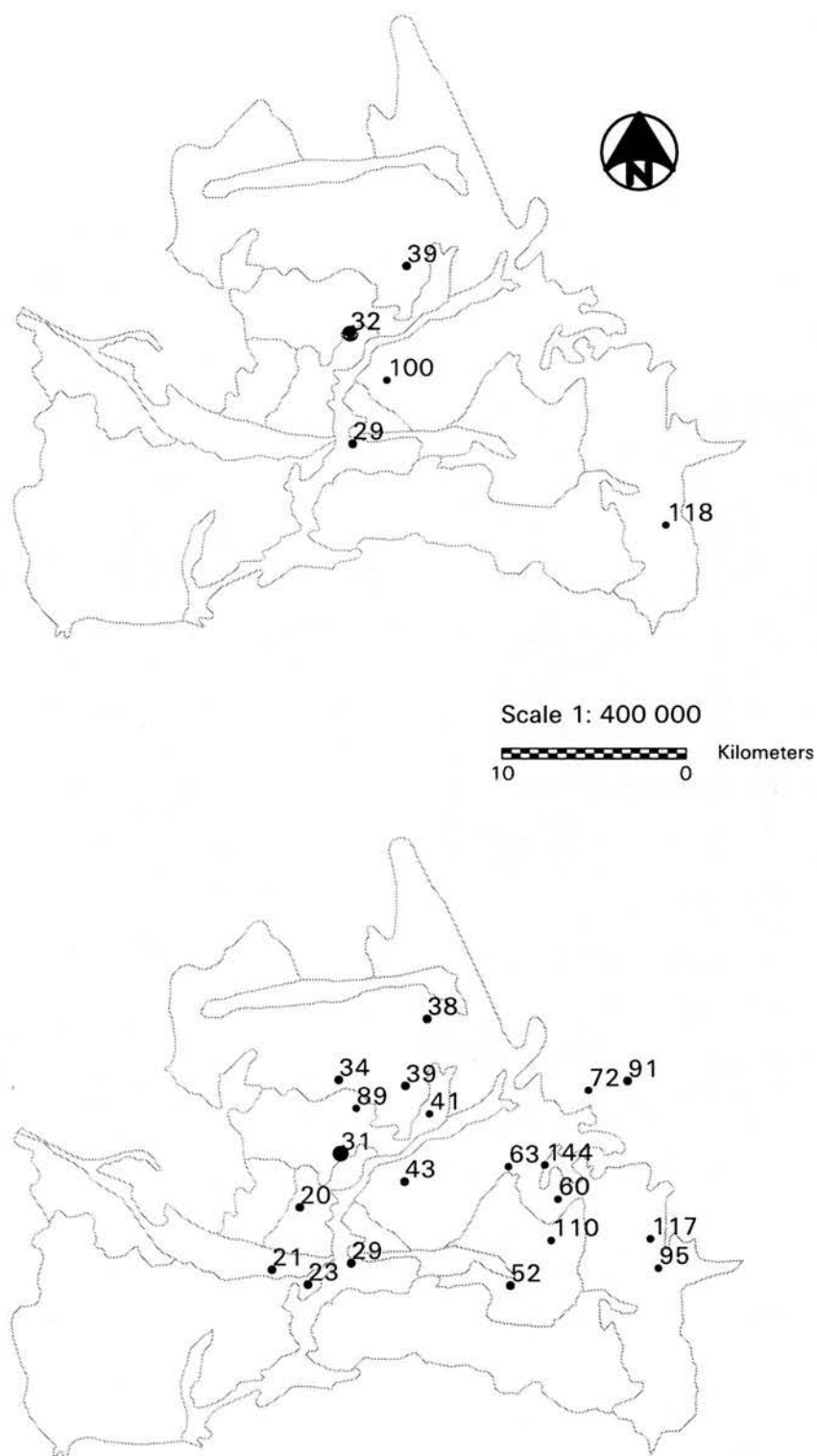


Figure 4.1 Settlement distributions on the Carsamba alluvial fan in early prehistoric (top) and Early Chalcolithic (lower) periods. The details of numbered locations are listed in Appendix 1. Filled circles indicate the relative size of individual settlements.

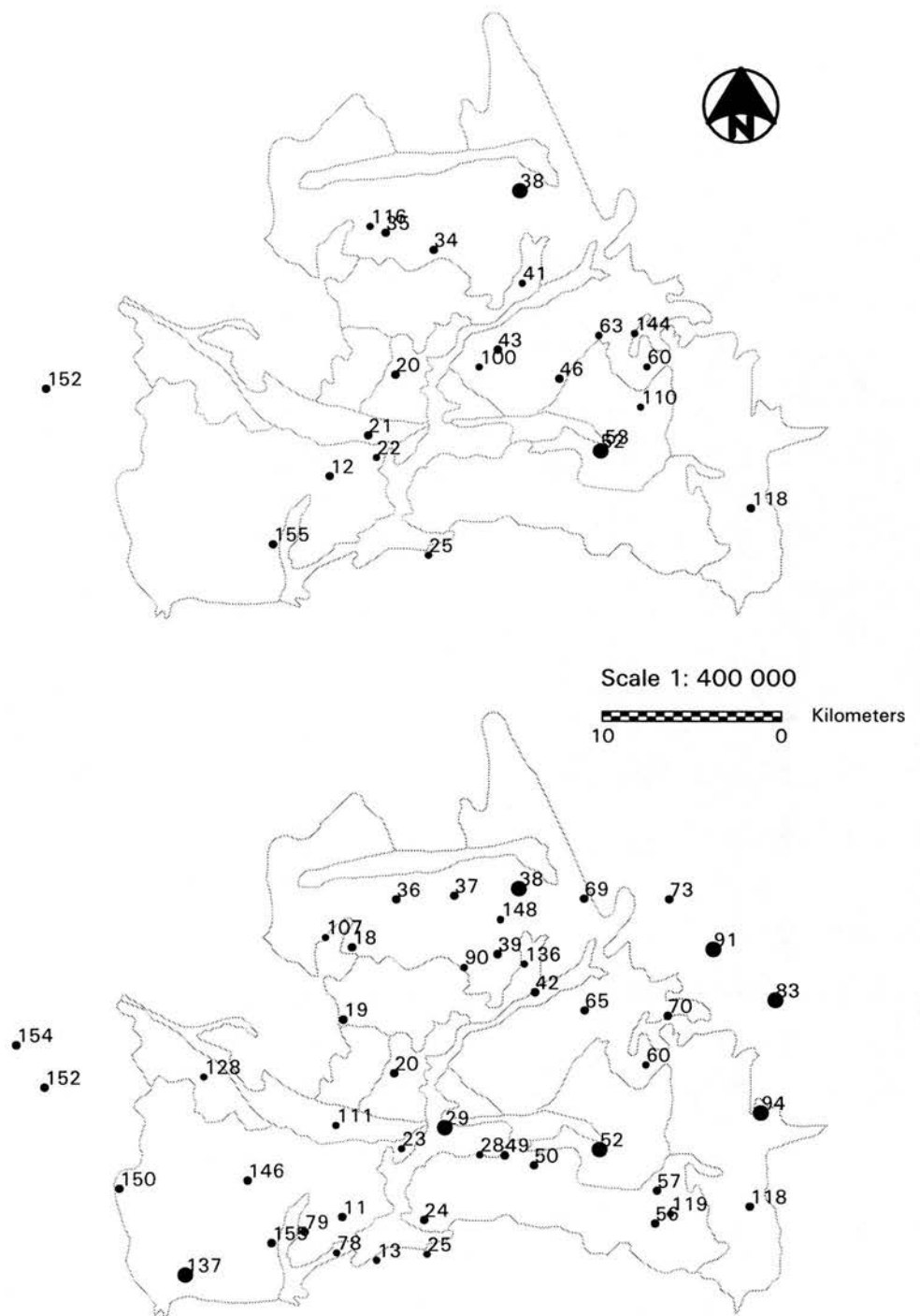


Figure 4.2 Settlement distributions on the Carsamba alluvial fan in the Later Chalcolithic (top) and Early Bronze Age I-II (lower) periods. Details of numbered locations are listed in Appendix 1. Filled circles indicate the relative size of settlements.

Taştömek and Bozlan Höyük are centrally located within a concentration of settlements on the eastern fan. Muşluk and Turkmen Kara Höyük South (French 1970a) occupy isolated positions at the eastern edge of the mapped settlement distribution. Küçükköy (French 1970a), Mezarlık II and Kızıl Höyük I form a cluster in the central fan. The northern-western area of the fan was evidently unoccupied in the Early Chalcolithic, as no trace of Early Chalcolithic occupations has yet been recognised at the large Early Bronze mounds of Karaca Höyük, Kızlar Höyük, or Domuzboğazlıyan Höyük (Mellaart 1961, French 1966).

The settlement distributions reconstructed from field survey evidence suggest that freely drained sites are favoured for settlement in the Early Chalcolithic, perhaps a response to the risk from flooding in this dynamic floodplain environment. However, the potential role of differential recovery factors, particularly the loss of settlement evidence from low lying and more heavily alluviated central fan locations, may contribute to this apparent distribution. İrmik Höyük and Sarlak Höyük I are sited on palaeoshoreline ridgelines of the former lake, while other sites including Taştömek, Musalar and Kuşlu Höyük II are located on slight elevations in rolling sandy and gravelly terrain. Elsewhere, as at Çatalhöyük, there is the possibility that the earliest settlements were located on the raised banks of former stream channels.

At Çatalhöyük West, the absence of later cultural deposits enables an impression of the size of the Early Chalcolithic settlement to be gained from its present extent, although an unknown area of lower slope of the mound remains buried beneath later alluvium (Roberts 1982: 387, Roberts et al 1996: 37-39). The size of Çatalhöyük West when compared to other Early Chalcolithic mounds indicates that Çatalhöyük remained a focus for local populations in the Early Chalcolithic as in the preceding Neolithic. Even in the absence of any estimate of the area buried by later alluviation, the extent of the visible mound at around 300 metres in diameter establishes Çatalhöyük West as the largest Early Chalcolithic settlement on the Çarşamba fan. In spite of this prominence within its contemporary settlement distribution, the Early Chalcolithic mound at Çatalhöyük West is considerably lower and smaller than its

Neolithic neighbour, although the difference in size may partly reflect the relative duration of occupation on the two mounds.

At other Early Chalcolithic settlements, including Kızıl Hüyük I, İrmik Hüyük, Dedeli Hüyük and Sarlak Hüyük I, Early Chalcolithic pottery is found as a component within multi-period assemblages which include later and occasionally, as at Kızıl Hüyük I and Seyithan, earlier material. While no reliable estimate of the size of the Early Chalcolithic settlement is available at such multi-period sites, only at Samık Hüyük, Kârhâne Hüyük and Sarlak Hüyük I could the volume of later occupation deposits potentially obscure an Early Chalcolithic settlement even approaching the size of Çatalhöyük West.

Elsewhere across the fan, Early Chalcolithic settlements occur as low mounds of relatively small area. The visible settlement remains at these sites frequently cover an area of less than one hectare. Examples of smaller settlements include: Kuşlu Hüyük II, Çinili, Mezarlık II, Musalar, Muşluk, Taştömek, Bozlan Höyük and Turkmen Kara Hüyük South (Baird 1997, Mellaart 1961, French 1970a). While the reconstructed distribution of Early Chalcolithic settlements is likely to be incomplete and systematically biased towards the under representation of settlement remains in some parts of the fan, as discussed in Chapter 2, the available evidence suggests a network of small regularly spaced settlements in this period (French 1970b, Yakar 1985).

The unobtrusive character of many of the surveyed Early Chalcolithic mounds suggests that the reconstructed settlement distribution for this period is likely to be incomplete. Few of the smallest mounds appear on maps, most being located by field-walking or from satellite remote sensing data. Çinili and Mezarlık II are examples of sites that are effectively at the level of the surrounding terrain. The detection of such unobtrusive sites must be considered unlikely in the presence of cultivated crops. Kuşlu Hüyük II, Muşluk, Mahsen Hüyük and Taştömek are located in hummocky terrain and are only identifiable as archaeological features when walked. French remarks that Turkmen Kara Hüyük South was discovered by chance

while photographs were being taken and comments that similar sites are likely to have been overlooked during field survey (French 1970a: 141).

In addition to Çatalhöyük, evidence for continuity of occupation from the preceding Neolithic period is found at Kızıl Hüyük I and Seyithan.

#### 4.3.4. The Later Chalcolithic period.

The mapped settlement distribution for the Later Chalcolithic contains a similar number of sites to the preceding Early Chalcolithic period, but extends beyond the limits of the earlier distribution. The exception to this general pattern is found to the north and west of the large settlement at Çatalhöyük West, this area apparently being abandoned, or not used for the purpose of permanent settlement throughout the Later Chalcolithic period (figure 4.2). The form of the Later Chalcolithic settlement distribution may be likened to a letter T, with its stem parallel to the axis of the modern Orta Çarşamba and its top aligned north-west to south-east across the older backswamp deposits of the fan. Outside of this general distribution, isolated settlements occur at Okçu Hüyük I and Dirabey Hüyük on bajada soils to the south and west.

Early Chalcolithic settlements in raised locations on palaeo-shoreline features and rolling sand and pebble ridges continue to be occupied in the Later Chalcolithic at İrmik Hüyük, Sarlak Hüyük I, Taştömek and Kuşlu Hüyük II. The new settlements at Halaç Höyüğü, Boyalıömek, Sarlak Hüyük II and Alemdar are also located in freely drained situations. While this apparent preference for raised settings presents obvious practical advantages in a floodplain environment, the loss of small settlements in more heavily alluviated areas may again contribute to the observed distribution (e.g. Brookes et al 1982: 296).

A general pattern of small settlement size appears to continue from the Early Chalcolithic into the Later Chalcolithic (French 1970b:1). Baird has also observed that the Later Chalcolithic period sees a swathe of new small sites, all under three



hectares in area, appearing on the fan (Baird 1997: 13). The new settlements at Sarlak Hüyük II, Avrathanı, Araboğlu, Kartaltömeği III and Alemdar all fit this description. Of the larger multi-period mounds, only at Sarlak Hüyük I and İrmik Hüyük is there the possibility that larger Later Chalcolithic settlements could be concealed beneath later occupation levels.

Mellaart proposes a shift in settlement distributions at the end of the Early Chalcolithic and again at the end of the Later Chalcolithic, such that Later Chalcolithic remains are "...in nearly every case found on sites where no earlier or later remains were encountered" (Mellaart 1963: 199). This shift in settlement distributions proposed by Mellaart illustrates the difficulty of interpreting negative evidence in the context of mound surveys, particularly where large scale patterns are extrapolated from the evidence at a small number of sites. Settlement patterns reconstructed on the basis of subsequent fieldwork now appear to contradict this theory of a shift in settlement distribution across all parts of the fan. There is evidence for continuity of settlement between the Early and Later Chalcolithic at Kuşlu Hüyük II, Taştömek, İrmik Hüyük and Bozlan Hüyük, while at Sarlak Hüyük there is evidence for both continued occupation of the old mound and for the construction of a new settlement in this period. More localised changes in settlement patterning appear to have occurred however at the transition from the Early to Later Chalcolithic, most notably in the central and north-western fan.

At Çatalhöyük West, the evidence for the abandonment of the Early Chalcolithic mound is clear in the absence of later occupation activity. Elsewhere, the nature of the archaeological record at multi-period mounds that are occupied in subsequent periods is such that intervals of abandonment is inferred from the absence of Later Chalcolithic components in the surface ceramic assemblage. On the evidence presently available, a pattern of settlement abandonment in the central and north-western fan appears to have been accompanied by intensified occupation, including the construction of new mounds in the southern and south-eastern fan, during the Later Chalcolithic period.

#### 4.3.5. The Early Bronze Age I and II period.

The Early Bronze Age I and II is of particular interest because of the density and variety of settlements and because of the apparent collapse in population levels which takes place on the Çarşamba fan at its close. Mellaart has described the Early Bronze Age of the Konya plain as a period of prosperity with few rivals on the Anatolian plateau (Mellaart 1963: 236). Certainly, the total number of Early Bronze settlements recognised to date is twice that of the preceding Later Chalcolithic period and includes some of the largest hüyük sites in the Konya Basin. There are currently forty-four mounds within the Çarşamba fan study area at which Early Bronze settlement evidence has been provisionally identified, while Mellaart estimates that there may be more than a hundred such settlements across the wider Konya plain (Mellaart 1963: 207).

The prominent features of the Early Bronze settlement distribution when compared to those of other periods are the large area that it encloses, the close spacing of settlement mounds and the appearance of a size-ranked hierarchy of settlements. Within the Early Bronze distribution, two prominent clusters of settlement activity can be identified. The first cluster is in the vicinity of the modern town of Çumra and comprises of an elongated grouping of sites conforming to the main channel of the modern Çarşamba Cayı. A second cluster occurs in the northern fan and takes the form of a linear grouping or alignment oriented east to west. Linear arrangements are also tentatively identified conforming to the recent historic (pre-irrigation) channel of the Sol Çarşamba and to the south of the palaeo-shoreline ridge, east of Seyithan Hüyük.

Other prominent features of Early Bronze I and II settlement include an area of reduced settlement density north of the shoreline ridge in the central fan (figure 4.2). Given the considerable height and extent of many of the remaining Early Bronze mounds, it seems unlikely that this lacuna can be explained by masking beneath later alluvial sediments.

A wide range of settlement sizes are represented in the Early Bronze period, from small, low mounds which appear at the modern fan surface as localised field level scatters, as at Kartal II, Mezarlık II and Deliali, to immense hüyük or 20 or more hectares as at Kerhâne Hüyük, Samık Höyük, Sırçalı Hüyük and Domuzboğazlıyan (French 1970b: 1). While a range of settlement sizes are documented for the Early Bronze I and II, the dominant type of settlement in this as in the Chalcolithic period appears to be the village sized community (Mellaart 1963, Yakar 1985: 36).

A further obvious feature of the Early Bronze I and II settlement distribution is that the largest mounds tend to be in locations near the edge of the fan, e.g. Alibeyhüyüğü, Kerhâne Hüyük, Türkmenkarahöyük, or beyond the fan altogether, as at Samık Höyük and Emirler Hüyük. As a consequence, while large mounds generally appear to occupy situations with good access to surface stream channels, they are not always surrounded by the best agricultural soils.

Settlement is particularly dense around the modern town of Çumra in the Early Bronze I and II period, where mounds may have several neighbours within a radius of just a few kilometres. The location of the largest Early Bronze mounds towards the outer edges of the settlement distribution is difficult to explain in terms of traditional locational, e.g. central place, theory (Baird 1996). While there is a clear settlement-size hierarchy in this period, the distribution of large and small settlements is not consistent with any obvious spatio-economic structure, such as the various K-landscapes formulated by Christaller.

French argues that the large mounds that emerge during the Early Bronze period at Samık Hüyük, Emirler Hüyük and Kârhâne Hüyük may not have been true urban centres (French 1970a: 142). The relatively close proximity of these large mounds in the northern Konya plain, (Samık and Emirler are less than 5 km apart), is interpreted as evidence that these are “perhaps... not political centres of the kind we know from the capital of a kingdom” (French 1970b: 3). By contrast, Mellaart argues that while most Early Bronze mounds are villages, “...many can only be cities, each with their citadel raised above the rest of the site” (Mellaart 1963: 207). Examples of ‘city’

mounds cited by Mellaart include Kârhâne Hüyük, Samık Hüyük and Seyithan Hüyük, although the mounds at Türkmenkarahöyük, Alibeyhüyüğü and Sarlak I might feasibly be added to this list.

The steep sloping sides and relatively small summit area of Seyithan distinguish it from the flatter profiles of most of the other large Early Bronze mounds. Seyithan dominates the natural ford where the Çarşamba breaches the sand and gravel palaeo-shoreline spit north of Çumra, and its steeply sloping sides suggest the presence of ramparts or similar defensive structure.

The two clusters of settlement activity that were earlier identified, one in the vicinity of the modern town of Çumra, and a second towards the northern edge of the fan, both represent the intensive occupation of areas which appear to be occupied for the first time in this period. The Early Bronze I and II period also sees an intensification of settlement in the south-eastern fan. To the north, the evenly spaced curving line of settlements between Karaca Hüyük I and Emirler Hüyük, is a further feature in this period.

The overall pattern in the Early Bronze Age I and II is of a dense distribution of settlements spread across the cultivable area of the fan, suggesting correspondingly intensive patterns of land-use. Sites such as Kartaltömeği II, Mezarlık II and Deliali, suggest the existence of smaller settlements, perhaps equivalent of hamlets similar in size to the modern Turkish *çiftlik*, which would constitute an additional tier within the Early Bronze settlement size distribution, beneath the level of the nucleated 'village' or 'town'. Beyond the main settlement distribution, the line of settlements running north-west from Alibeyhüyüğü in the direction of Karahöyük Konya indicate that bajada areas along the western edge of the Konya basin were also exploited during the Early Bronze period.

Continuity of settlement is apparent at approximately half of the locations occupied during the preceding Later Chalcolithic period, while at Dedeli Hüyük and Kızıl Hüyük I, locations which were previously settled during the Early Chalcolithic are

reoccupied. This general pattern of continuity is somewhat masked by the large increase in the number of settlements after the Later Chalcolithic, and by the expansion into apparently previously unoccupied areas of the fan. Mellaart cites similarities in the ceramic assemblages of the Later Chalcolithic and Early Bronze I period as evidence for cultural continuity between the two periods (Mellaart 1963: 203).

A feature of the Early Bronze settlement distribution identified from the earliest surveys, is that many of the settlements apparently abandoned at the end of the Early Bronze II are never reoccupied (e.g. Mellaart 1963: 210, French 1970a). The reconstructed Early Bronze I and II settlement distribution may be relatively complete when compared to other periods both because of the absence of masking beneath later occupation levels, and because settlements in this period tend to be highly nucleated, forming obtrusive mounds that are readily located in the field. The absence of later occupation levels at many Early Bronze mounds, while of considerable interest as a feature of the settlement record itself, also permits an assessment of the relative size of individual settlements. While the exposed surface of a partly buried mound may provide a potentially misleading indication of its original extent (e.g. Brookes et al 1982: 299), gross differences in the relative size of local Early Bronze mounds can be identified with some confidence from their modern extent.

#### 4.3.6. The Early Bronze Age III period.

Mellaart describes the Early Bronze Age III settlement evidence from the Konya plain as “scanty in the extreme”, tentatively dating just three settlements in the plain to this period compared to more than a hundred in the preceding Early Bronze Age I and II (Mellaart 1963: 236). Mounds on the Konya plain identified by Mellaart as producing evidence of possible EB III occupations are; Kara Hüyük Konya, Seyithan Hüyük and Zencirli (Mellaart 1963). Of the three mounds mentioned by Mellaart, only one, Seyithan Hüyük, is located within the study area of the present project.

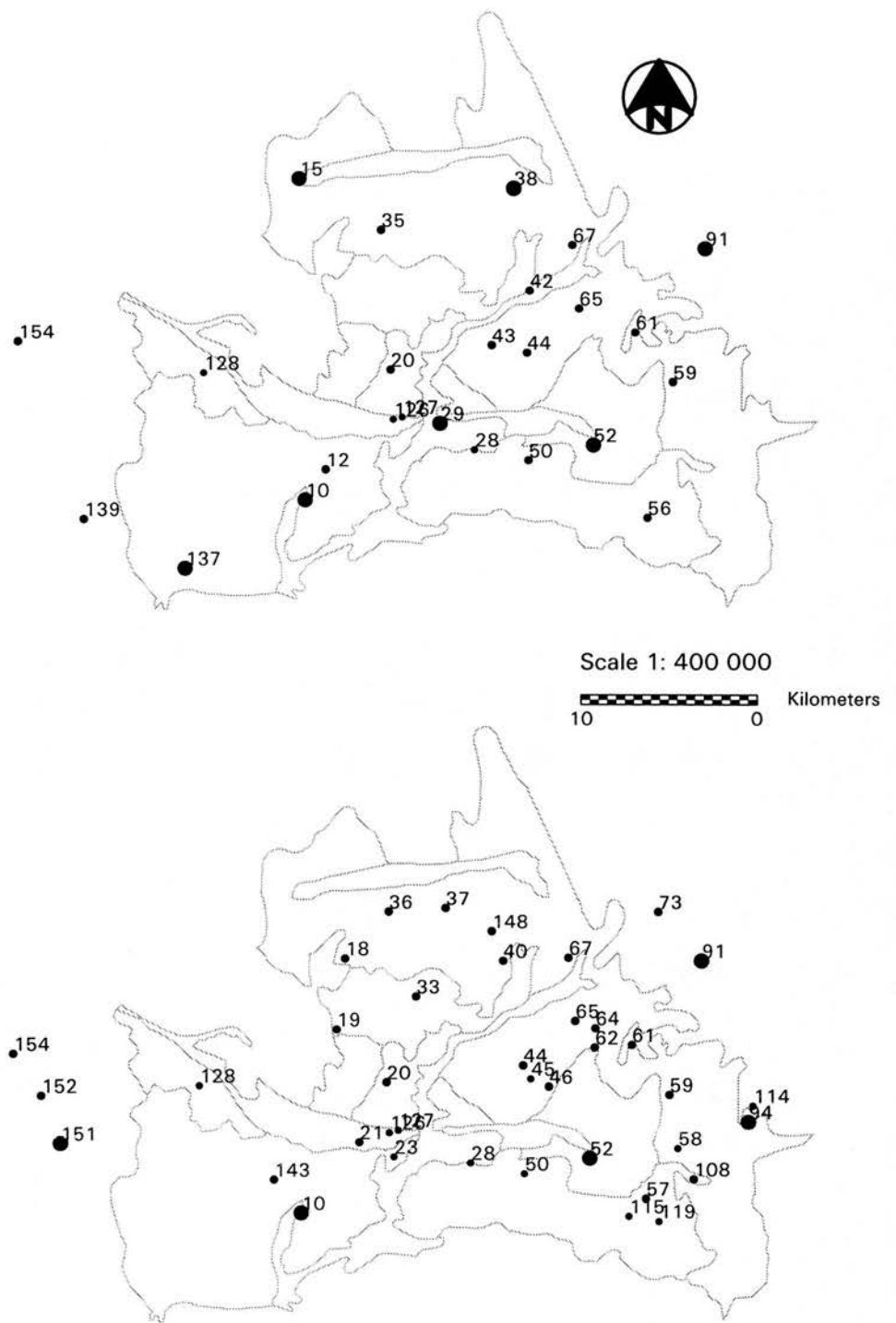


Figure 4.3 Settlement distributions on the Carsamba alluvial fan in the second millennium BC (top) and Iron Age (lower). The details of numbered locations are listed in Appendix 1. Filled circles indicate the relative size of settlements.

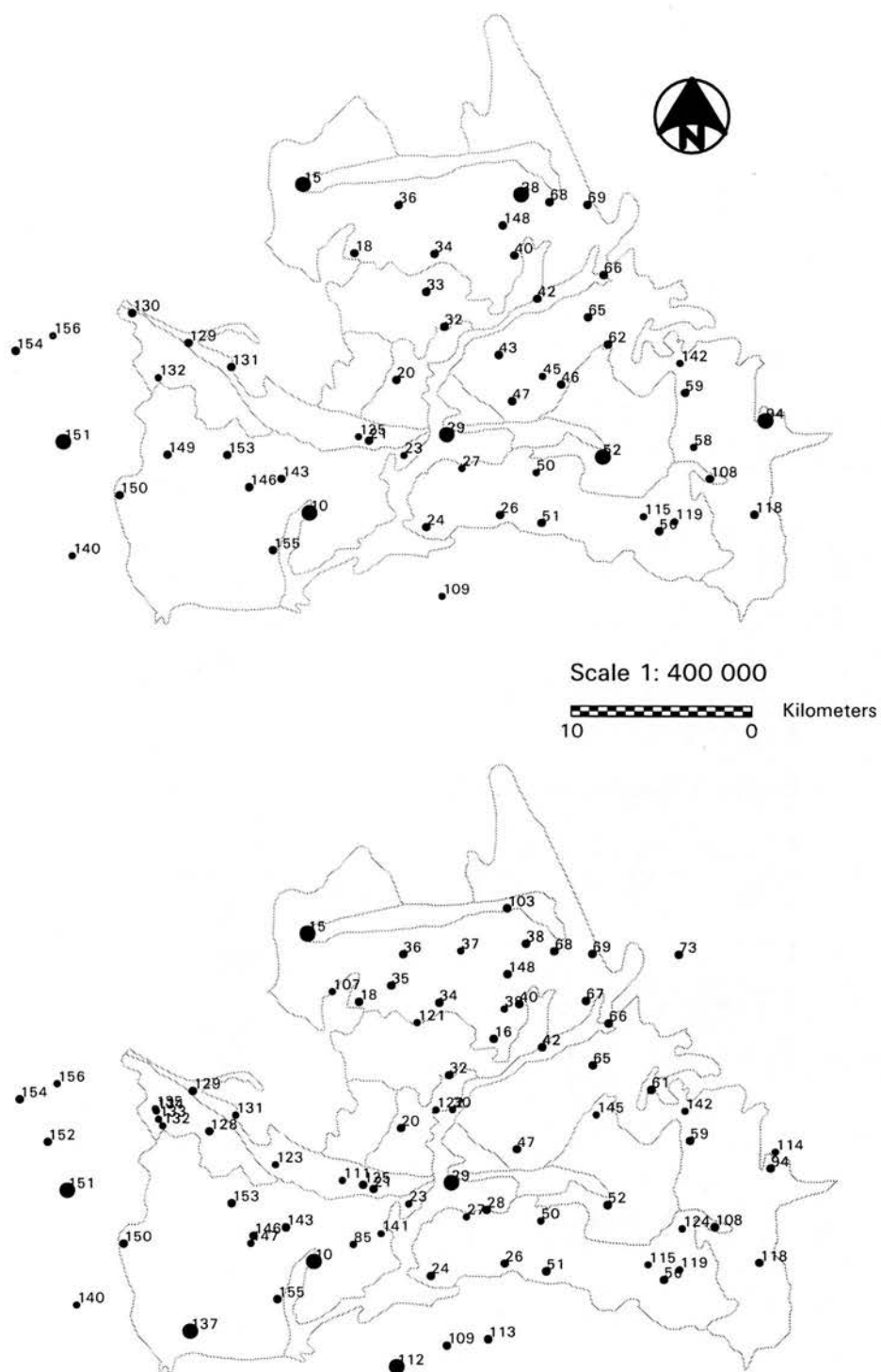


Figure 4.4 Settlement distributions on the Carsamba alluvial fan in the Hellenistic period (top) and in the Roman and Byzantine period (lower). Details of numbered locations are listed in Appendix 1. The filled circles indicates the relative size of settlements.



The identification of Early Bronze Age III settlement is hampered by the lack of a securely provenanced local ceramic type assemblage. A particular consideration is that stylistic elements in the Early Bronze Age III ceramic repertoire may persist into the following Middle Bronze period. The Early Bronze III date at Seyithan Hüyük, as at the other two sites on the plain, is based on red cross bowls recovered during surface survey. Mellaart comments that EBA III pottery of the type excavated from Kara Hüyük levels V through VII was not found during his own mound surveys on the plain. Bead rim bowls of the type found by Alp at the EBA III to Middle Bronze transition (levels V and IV) at Kara Hüyük Konya, were however found at Domuzboğazlıyan and at Üçhüyük on the fan. A possible fragment of a *depas* cup in polished red ware was also recorded by Mellaart at Üçhüyük, but he comments that these transitional ceramic forms could equally derive from the later Middle Bronze occupation layers present at both mounds (Mellaart 1963: 236).

At the time of writing, the Çatalhöyük Regional Survey has provisionally identified Early Bronze III pottery at Alibeyhüyüğü, Samık Hüyük, Seyithan Hüyük, Ürümdü Hüyük, Çarıklar Hüyük, Kerpiç Hüyük and Tenekli, although Mellaart raises the possibility that masked Early Bronze III occupation levels may exist at a number of other settlements on the Çarsamba fan (Mellaart 1963). With regard to this possibility of masked levels, it should be noted that while there are questions about the archaeological visibility of local Early Bronze III ceramic material, the recognition of Early Bronze III pottery at the locations listed above indicates that the scarcity of evidence for Early Bronze III settlement cannot be wholly attributed to visibility issues.

#### 4.3.7. The second millennium BC.

Settlement distributions in the second millennium BC resemble those found in the Early Bronze I and II, with the significant difference being the reduced density of sites in the later period. Of the twenty-six second millennium settlement locations provisionally identified from field surveys, half were formerly Early Bronze I and II settlements (Figure 4.3). The similarity between the Early Bronze Age and second

millennium settlement distributions is particularly pronounced at the largest settlement sites, a feature noted by Mellaart (Mellaart 1958). The settlements at Alibeyhüyüğü, Seyithan Hüyük, Samık Hüyük, Kârhâne Hüyük and Sarlak Hüyük I are key population centres in both periods.

The most prominent feature of the second millennium settlement distribution is the reduction in the total number of settlements when compared with both earlier and later periods. This pattern is not limited to the fan, but extends across the whole Konya plain. Mellaart estimates that about one in three settlement mounds on the plain show evidence of occupation during second millennium (Mellaart 1958: 311-312). Within the Çarşamba fan study area, the twenty-six settlement mounds provisionally identified to the second millennium may be contrasted to the forty-four Early Bronze I and II, and forty Iron Age period settlements.

The reconstructed second millennium settlement distribution includes two linear arrangements of mounds that converge on the large settlement of Samık Hüyük at its eastern edge. To the north, Domuzboğazlıyan Hüyük, and Samık Hüyük form an east to west alignment, with Kârhâne Hüyük equidistant between the two. A second alignment extends south-west from Samık Hüyük towards Alibeyhüyüğü, consisting of Halaç Hüyük, Kopruxeri, Seyithan and Sırçalı Hüyük. Some areas of the fan are apparently unoccupied during the second millennium, a prominent example being the area between the settlements at Dedeli Hüyük, Avrathanı and Kârhâne Hüyük (figure 4.3).

In view of the small number of second millennium mounds, a greater average separation between neighbouring settlements when compared with other periods is to be expected. However, the regularity of settlement spacing and absence of clustering which also characterise the settlement distribution in this period would not necessarily arise from a simple reduction in the total number of settlements and are interpreted as significant features of the second millennium settlement distribution.

The recent discovery of smaller settlements dating to the second millennium indicates that contemporary populations were not restricted to the larger mounds identified in earlier surveys. The unobtrusive nature of some recently recorded second millennium settlements raises the possibility that other unrecorded settlements may exist elsewhere across the study area.

The archaeological ‘visibility’ of second millennium ceramic material may itself further contribute to the non-recognition of settlement evidence from this period. Archaeological ‘visibility’ may be especially significant at the transition from the second millennium to the Iron Age, a period characterised for Mellaart by the ‘unrelieved drabness’ of its ceramics (Mellaart 1958: 325).

The overall pattern of reduced settlement frequency accompanied by continued occupation at larger Early Bronze mounds may be partly explained by the aggregation of populations from smaller settlements. Although population aggregation has elsewhere been proposed as a natural development following the emergence of large ‘city’ mounds during the Early Bronze period (e.g. Adams 1970: 3), it seems unlikely to fully account for the absence of second millennium occupation at many former Early Bronze mounds (Mellaart 1958: 312).

#### 4.3.8. The Iron Age period.

The distribution of mapped Iron Age settlement differs markedly from that of the preceding second millennium and Early Bronze I and II periods. A notable feature is that some of the larger Early Bronze Age I and II and second millennium settlement locations are unoccupied in the Iron Age. There are two tightly clustered groups of settlements in the north-eastern fan to the east of the modern village of Karkın in this period. Of these, the more western group encompasses Kopruxeri, Kızıl Hüyük II and Araboğlu Höyüğü. The second group of Iron Age settlements comprises Halaç Höyüğü, Bostantömek and Kuşlu I Hüyük. There is also evidence for the

reoccupation of areas last settled in the Early Bronze Age at several sites in the north-western fan, and also to the south and east at Kuru Hüyük, Kanlı Hüyük and Kepir Hüyük.

Of the twenty-six second millennium mounds identified on the fan, fifteen are subsequently occupied in the Iron Age period. While there is also re-occupation of Early Bronze Age I and II settlement locations at a further eleven sites, continuity with earlier settlement patterns is hardly a general characteristic of Iron Age settlement activity on the fan. More than a third of Iron Age settlements are in locations settled for the first time in this period.

A prominent elongated void in the settlement distribution is located along the course of the modern Orta Çarşamba, north of the shoreline ridge where it passes through the village of Karkın, separating the east and west of the fan (figure 4.3). A second area yet to produce evidence for Iron Age occupation, or indeed for occupation in any period after the Later Chalcolithic, is centred north and west of Kuru Hüyük and north of the mounds at Sarlak. New settlements at Çingene Hüyüğü and Kapıdallı Hüyük are located in areas of the fan that were not occupied during the Early Bronze Age or second millennium. A series of settlements along the eastern edge of the fan at Koseli Hüyük, Türkmenkarahöyük, Kanlı Hüyük, Kepir Hüyük, Kuru Hüyük and Üçhüyük indicate a more intensive occupation of this part of the fan during the Iron Age when compared with earlier periods. Similarly, the large new Iron Age settlement at Saksığsan Hüyük and continued occupation at Çarıklar Hüyük indicate intensive occupation of the bajada soils to the west of the fan.

Ceramic material collected from non-mound sites begins to form an important component of the mapped settlement evidence from this period, with extensive Iron Age artifact scatters recorded south of Dedeli Hüyük, at Kızıl Hüyük III and at Kopruxeri. These extensive scatters suggest settlement layouts that are quite different to the highly nucleated settlements of earlier periods.

There is some evidence for a settlement pattern favouring slightly elevated locations. This characteristic is illustrated by the cluster of mounds located among sandy ridgelines east of Karkın village that includes Bostantömek, Kuşlu Hüyük I and Halaç Höyüğü. A similar locational preference is found at Beşkilise, İrmik Hüyük, Kanlı Hüyük, Koseli Hüyük and Dedeli Hüyük. As in other periods, this pattern may be reinforced by a systematic bias towards the recovery of settlement evidence from areas least affected by later alluviation. The Iron Age settlements at Beşkilise, Kuşlu Hüyük I, Halaç Höyüğü and Kepir Hüyük are adjacent to low lying areas which form shallow seasonal water bodies or marshes under modern conditions, raising the possibility that access to these low lying areas influenced the location of these settlements.

Iron Age settlements on the fan tend to be relatively small, with few exceeding six hectares in size (Baird 1997). Exceptions to this general observation occur at Türkmenkarahöyük, Samık Hüyük, Sırçalı Hüyük and Saksığsan Hüyük. At Türkmenkarahöyük, a c.30 hectare Hellenistic settlement at the eastern edge of the fan, ceramics in the walls of deep gulley systems and in slope wash deposits indicate an underlying Iron Age settlement, although its extent is difficult to estimate because of the deep mantle of Hellenistic occupation remains. Sırçalı Hüyük is one of the largest settlement mound on the Çarşamba fan, measuring over 35 hectares in extent and 30 metres in height. Here the Iron Age settlement is again obscured beneath Hellenistic and Roman and Byzantine occupation levels, and is evidenced only by the presence of re-deposited material at the surface of the mound.

The flat topped rectangular plan of the mounds at Kızıl Hüyük II and at Kınıkçı Hüyük are different from anything found in earlier periods and it is possible that these sites had some specialised, function. The close, regular spacing and symmetrical geometric configuration of the settlements to the east of the modern village of Karkın is also a distinctive feature within the Iron Age settlement distribution.

#### 4.3.9. The Hellenistic period

Settlement on the Çarşamba fan is particularly dense in the Hellenistic period, with individual settlements spaced at regular intervals across the fan (Baird 1997). While the majority of settlements in the Hellenistic period appear to be small, sedentary agricultural villages (Baird 1996b), there are notable exceptions to this pattern. A prominent local centre approximately 25 hectares in extent surrounds the large Early Bronze mound at Seyithan Hüyük (Baird 1997) while a 30 hectare raised settlement is found at Türkmenkarahöyük. Domuzboğazlıyan, Kârhâne Hüyük and Saksığsan also appear to have been important population centres in the Hellenistic period. Areas of reduced settlement density are evident in the central fan and on the playa area to the east of the shoreline ridge, as in the preceding Iron Age distribution.

There is some evidence for the continuity of settlement locations from the Iron Age with nearly half of Hellenistic settlements in locations occupied in the preceding period. Against this background of continuity there is also a pattern of new settlements being established, a cluster of new settlements to the north-west of Sırçalı Hüyük being particularly prominent. The bajada areas to the west and south are included in this pattern. Seyithan Hüyük, Cingene Höyüğü and Uçhüyük I, there is the reoccupation of locations last settled during the Early Bronze and second millennium, although the large Early Bronze and second millennium mounds at Alibeyhöyüğü, Samık Hüyük, and Erminler Hüyük are apparently unoccupied in this period. In the south-eastern fan, occupation continues at the former Iron Age settlements of Üçhüyük, Türkmenkarahöyük and Kepir Hüyük, but Kuru Hüyük is abandoned.

The overall picture is of an intensification of settlement activity throughout the study area during the Hellenistic period. This intensification is reflected in the almost 40% increase in the number of settlements compared to the previous period but also in a settlement distribution that is strikingly uniform in terms of both inter-settlement spacing and the relative intensity of occupation in different parts of the fan.



#### 4.3.10. The Roman and Byzantine period.

On the basis of aggregate site area, the Roman and Byzantine period witnesses a population maximum on the plain (Baird 1997: 13). Settlements are both more numerous than in the preceding Hellenistic period and generally also of greater extent. The almost universal occurrence of intrusive Roman and Byzantine burials into earlier mounds of all periods is an additional indicator of intensive occupation during this period. A prominent feature of the Roman and Byzantine settlement distribution is the further intensification of settlement in the central fan to the north of Çatalhöyük and in the south-western part of the study area.

Occupation materials of Roman and Byzantine date are widely distributed across the modern land surface of the fan, and tend to form extensive artifact scatters, even in heavily alluviated areas such as that around Çatalhöyük. There is also evidence of considerable continuity with Hellenistic settlement distributions, with the notable exception of the central-eastern fan where the locations of Hellenistic settlements are generally abandoned. This pattern of continuity is accompanied by the expansion of some small Hellenistic settlements into larger settlements of ca 12 - 18 hectares in area and into small towns. There is also evidence for intensified settlement of the bajada areas west and south of the fan, including a new major population centre at Sayalı, which is estimated to have covered an area of around 45 hectares in the Roman and Byzantine period (Baird 1997).

The large Roman and Byzantine settlement at Sayalı and the neighbouring settlement of Gafurağıl are sited at the lower end of gulley systems draining upland areas to the south of the fan. The clear association between the settlements and these features suggests that access to the seasonal runoff from upland areas may have been important during the Roman and Byzantine period.



#### 4.4 Summary

The preliminary results of the Çatalhöyük Regional Survey provide a new basis for investigation of the past settlement history of the Çarşamba alluvial fan. While some features of the spatial patterning observed in reconstructed settlement distributions may be attributed to the differential preservation and recovery of the archaeological evidence for past settlement activity, it is clear that others reflect changing patterns of past settlement and land-use within the alluvial landscape of the fan. The analysis of reconstructed settlement distributions on the Çarşamba fan is the topic of the next chapter.

## **Chapter 5: Analysis of past settlement distributions**

### **5.1 Introduction**

The premise of archaeological spatial analysis is that human activity is patterned and that this patterning is reflected in the form of spatial relationships within the archaeological record (Clarke 1977). However, it is also apparent that individual societies respond differently to similar ecological and demographic situations (Leach 1973: 767). A recurrent theme in the interpretation of past settlement distributions is the difficulty of distinguishing between environmental, cultural and economic influences on settlement. Even where settlement distributions can be plausibly reconstructed cultural factors will systematically distort an ideal human ecology (Bintliff 1988: 142).

The geographer is generally presented with a situation in which all components of a settlement system are available for analysis, the archaeologist, by contrast, is restricted to those patterns that can be discerned from partial and often biased data (Rose and Altschul 1988: 175). The likelihood that the settlement patterns reconstructed for the Çarşamba fan are incompletely mapped is discussed in chapters 2 and 3. In particular, it is evident from field survey that there is probable bias towards the non-recovery of some settlement types. There may also be a pattern of reduced recovery of settlement activity dating to earlier periods, arising from the progressive burial of older sites beneath later alluvial sediment. As a result of these factors, the completeness of a mapped distribution is expected to vary in different parts of the fan and in different periods.

Archaeologists are frequently concerned with reconstructing the settlement pattern for a particular archaeological period. Adams proposes that a more coherent approach is to consider the long-range settlement history of a region as a continuous record where the changing distribution of settlements in different periods reflect past human adaptation to and exploitation of a particular setting (Adams 1965: viii). The challenge faced by human communities throughout prehistory appears to have been the development of resilient adaptative strategies (Adams 1988: 13).

The scale of a spatial process will affect the choice of methods used in analyses. Large-scale archaeological distributions containing integrated site systems or dispersed across landscapes can be described as macro-scale spatial processes (Clarke 1977: 11-15). Other aspects of past settlement activity may occur at smaller scales (Gaffney and Gaffney 1988). The present research is concerned with the patterns of past land use and with the spatial interaction between neighbouring settlements in different periods. Aspects of the settlement record selected for investigation include settlement clustering and variation in the distribution and intensity of settlement activity in different areas of the fan over time. The calculation of nearest neighbour values for reconstructed past settlement distributions on the Çarşamba fan reveal that a settlement of any period is likely to have two or more neighbouring settlements within a distance of less than 5 kilometres (see Table 5.1 below). Emphasis has therefore been placed on the investigation of persistence structures at an inter-settlement spacing of 5 kilometres and less in order to explore the spatial relationships that existed between settlements and their first nearest neighbours in different periods.

## 5.2 Data lineage and representation issues.

The physical geography of the study region and the dating frameworks used to organise the archaeological evidence for past settlement are described in Chapters 1 and 2. Discrete physical environmental settings can provide naturally delimited study regions for the investigation of past settlement distributions, avoiding the need to define arbitrary study region parameters (Altschul and Nagle 1988: 277). The fertile and relatively well watered alluvial fans lain down by rivers entering the semi arid Konya-Ereğli basin are suggested to provide a naturally delimited region of this type. The present study centres on the alluvial fan of the Çarşamba Cayı, the largest of the several rivers entering the Konya-Ereğli basin. The length of the occupation record of the Çarşamba fan, its productive agricultural soils and central location, suggest that its settlement history may reflect patterns that are of wider significance within

Access to topographic base mapping at scales suitable for the proposed analysis (i.e. 1: 50,000 or 1:25,000 scale) presented difficulties in the early stages of the project because the distribution of these maps is restricted by the Harita Genel Komutanlığı (HGK), the Turkish national mapping agency. In 1996, for example, the most detailed map series available for sale to the public in Turkey was printed at a scale of 1: 250,000. Security protocols established between Turkey and other NATO member states have also served to restrict access to mapping outside Turkey (Parry and Perkins 1987: 355).

The spatial data used in this project are organised according to the projection and coordinate system used in topographic maps produced by the HGK for this region of Turkey (i.e. Transverse Mercator (Gauss Kruger) projection, International Spheroid (1909), UTM zone 36). Base mapping for settlement locations, streams, roads and settlements and a network of ground control points for the geo-coding of satellite imagery were traced manually from 1:25,000 map sheets onto drafting film before being digitised as separate GIS coverages using the ARC Digitising System (ADS). Digitised coverages were edited within the ARCEDIT module of ARC/INFO, then transformed to coordinate tic coverages created from manually entered coordinates using the ARC TRANSFORM command. Sets of six tic coordinate locations were used to transform each digitised map sheet. The resulting edited and transformed coverages were then merged into a unified 1,400 square kilometre coverage incorporating the study region by means of the ARC MAPJOIN function.

Information on modern soils distributions was obtained from the 1:200,000 scale soils map of de Meester (1970). A sub-area of this map, extending beyond the limits of the Çarşamba fan was traced manually onto drafting film and digitised into ARC/INFO in a similar manner to the topographic maps. The soil map published by de Meester was originally prepared with reference to 1:25,000 topographic maps of the area before being generalised for publication at the larger scale (de Meester 1970). As the soils map does not reference the coordinate system of the original

1:25,000 mapping, coordinates for a network of prominent canal, road and track intersections common to the two set of maps were identified from the 1:25,000 series map sheets and used as control points to register the digitised soils coverage to the coordinate system used in the other coverages.

The settlement database was intended to provide a comprehensive map of past settlement based on the available archaeological survey evidence. Settlement locations were fixed from 1:25,000 scale topographic maps where their position was marked. Where unrecorded or otherwise unmarked settlements were located during field survey, their locations were fixed by reference to 1:25,000 scale maps in the field. The locations of a small number of settlements that were neither visited in the field nor marked on maps were obtained from surveyors' records on file at the British Institute of Archaeology at Ankara (French 1966).

The precise representation of the size and shape of settlements in all periods was considered unnecessary for the purposes of proximity analysis, and also as an impractical objective given the nature of the archaeological evidence. With regard to defining the size of past settlements, it is noted that many past settlements on the Çarşamba fan have multi-period occupation histories. Multi-period settlements are likely to have varied in size at different times so that their modern extent may not necessarily reflect their extent at a particular period in the past (French 1970b). The greater part of the study area has also been subject to long-term alluviation so that past settlements are buried to varying depths and their lower slopes or outer edges are often concealed beneath later sediments.

As an alternative to estimation of settlement size and shape, the coordinates of an approximate central point or centroid were determined for each settlement. Some 'double' mounds treated as separate entities during survey were considered as single settlements for the purposes of site location modelling purposes. The criteria used in such situations were that locations occupied in the same archaeological period and separated by less than 500 metres were treated as single locations. Sites in such close proximity probably reflect a localised expansion or shift in the locus of a settlement,

and effectively represent occupation of the same location at the scale of the present study. A complete listing of settlements, including centroid coordinates and the occupation periods recorded at each is provided in Appendix 1.

Some settlements located beyond the limits of the fan soils appear to be components of distributions centred on the fan, including the very large mounds at Samih Hüyük and Turkmenkarahöyük (Mellaart 1963: 207, French 1970b: 3). The study area was projected beyond the outer edges of the modern fan to incorporate these hüyüks. The inclusion of settlements located on the marl and of bajada areas bordering the fan avoided the imposition of an artificial boundary constraint, to the extent that settlement was not physically limited to fan soils, although intensive irrigation agriculture was probably concentrated on the fan in the past as it is today.

The representation of past settlement activity within a discrete or entity view, such as the georelational model outlined above, represents a radical simplification from the observed complexity of the archaeological record. An obvious difficulty in representing settlement distributions as point data is that actual populations occupy regions or areas in space. A theme in the exploration of settlement distributions has therefore been the creation of continuous settlement surfaces from point data in an attempt to identify sub-regions where populations were most concentrated or dispersed at different times in the past.

A further abstraction arises from the use of typological dating frameworks to partition continuous time into archaeologically defined periods, or epochs, of variable length. This use of periodised dating frameworks obscures a range of possible temporal relationships between settlements. The occupation activity at two settlements identified to the same 'period' could be simultaneous, consecutive or overlapping in duration for example. The potential complexity of actual occupation patterns is likely to increase according to the length of the period being investigated. A related and similarly intractable issue is the extent to which settlement distributions produced over different lengths of time can be meaningfully compared.

Langran (1993) suggests that the limited temporal information contained within 'event-driven' dating frameworks requires no sophisticated data structure and is most economically managed as ordinal data using a system of 'time stamps'. Managing temporal information in this way effectively represents settlement activity in different periods as a different type or level of event so that the multi-phase occupation of a settlement mound is considered as a series of events occurring at a single location.

### 5.3 Models of past population and land use

For Geographic Information Systems to be of value in the analysis of past settlement distributions, queries about past settlement activity must be capable of being formulated in spatial terms. At a fundamental level, this implies the modelling of past settlement as a spatially distributed process. Earlier, the representation of settlements as centroid point distributions was discussed. Point patterns of this type can be modelled as a combination of first-order and second-order influences on location (Bailey and Gatrell 1995: 32).

First-order influences are expected to be heterogeneous, varying with the local distribution of key limiting factors or resources, resulting in variation in the intensity of a process across the entire study region. In the case of past settlement distributions in semi-arid environments, an important first-order influence on the distribution of prehistoric agricultural settlements may have been proximity to stream channels. Adams suggests for example that access to the water resources used in irrigation was an important influence on the distribution of settlement in the Early Dynastic period on the Diyala floodplain in Iraq (Adams 1972: 745-746). Second-order influences are produced by autocorrelation or spatial dependence within the process itself, in this case the potential influence of settlements on each other. Influences of this type are expected to have a similar effect on settlement location irrespective of locality.

The spatial patterning produced by interaction between settlements may contain



regularities in settlement spacing, perhaps reflecting the presence of some minimum territory or sustaining area surrounding individual settlements. The presence of a 'sustaining area' or territory around settlements is often proposed as a model for past land use (e.g. Adams 1965, Vita-Finzi and Higgs 1970, Wilkinson 1982, Wilkinson et al 1996). For the purpose of the spatial analyses described in this chapter, a simplified concentric pattern of land use, decreasing in intensity with distance from the settlement has been assumed. The actual area exploited by early agricultural communities may have been rather more irregular, perhaps reflecting the local potential for diverting surface stream channels into cultivated fields (Adams 1965). The simple concentric form however, provides a reasonable model for past land use around early agricultural settlements on the Çarşamba fan. Remnants of historic field systems visible on satellite imagery surrounding villages on the Çarşamba fan at Üçhüyük and Ovakavağı conform to a regular concentric layout. Hillman also found this pattern at Aşvan and notes that fundamental economics of travel time to cultivated fields would have applied in pre-industrial periods (Hillman 1973).

Investigations into the first-order influences on settlement location traditionally involve the statistical testing of the association between past settlement location and independent (often environmental) variables thought to exert a potentially influence of settlement location. Two fundamental assumptions underlie this approach; i) that the settlement choices of prehistoric peoples were strongly influenced or conditioned by characteristics of the natural environment: ii) that the environmental factors which influenced these choices are portrayed, at least indirectly, in modern environmental variation (Warren 1990: 202).

In practice, the factors affecting settlement location are likely to be a complex combination of influences. Variables that have been employed in the investigation of archaeological location include: soils types (Wansleebe 1988, Gaffney and Stancic 1991, Hunt 1992); proximity to surface water resources (Brown 1979, Roper 1979, Judge 1973, Custer et al 1995), and elevation (Warren 1990b, Dalla Bona 1993). Examples of terrain-derived measures used to determine suitability for settlement or other activity include; slope, aspect, topographic form, drainage, shelter, cost-effort

surfaces, line of sight and viewshed or vantage (e.g. Brown 1979, Kvamme 1984, Kvamme 1988, Kvamme 1992a, Hasenstab and Resnick 1990, Gaffney and Stancic 1991, Wheatley 1995, Gaffney et al 1995, Wheatley 1996).

The profiling of settlement location in terms of environmental correlates is effectively a technique for the investigation of first-order influences on settlement distribution. Techniques such as site catchment analysis (SCA), the construction of Thiessen polygons, and Central Place Theory (CPT), are used to investigate second-order or spatial autocorrelation structures. The study of possible first-order influences on settlement within the Çarşamba fan study area is constrained by the lack of detailed knowledge about the past environments that were coeval with specific settlement distributions. The investigation of second-order effects is restricted by the limited resolution and variable precision of the available dating framework, and by uncertainty over the contemporaneity of settlements identified to a common archaeological 'period'.

Kvamme asserts that approaches based on the analysis of settlement location alone lack explanatory power when compared to those that investigate the environmental or other independent variables associated with settlement location (Kvamme 1988a: 339). Where sample data are used to develop a classification capable of being projected over a larger region for the purpose of site location, the more powerful approach will combine the calculation of trend surfaces with models developed using correlation methods (e.g. multiple logistic regression) (Kvamme 1988a: 381).

The physical geography of the Çarşamba fan study area and the lack of detailed knowledge of past environments restrict the application of traditional covariance based methods (e.g. Savage 1990). This approach is generally impractical on the Çarşamba fan because the distribution of modern soils is the product of processes that postdate much of the archaeological settlement record (French 1970a: 139). The Çarşamba fan is also a strikingly flat landscape providing little scope for terrain-derived analyses based on elevation, topographic form, slope or aspect. Similarly, the combination of open landscapes and raised *hüyük* settlements provides near-

universal intervisibility between locations on the fan, with viewsheds that extend far beyond the limits of the study area in all directions. Relic channel features visible in the walls of irrigation canals and on satellite imagery also indicate that the surface streams crossing the fan have shifted their courses numerous times in the past. For the most part therefore, the 'environmental correlates' of past settlement distributions are obscured by later alluvial sediments.

Archaeologists engaged in spatial analysis are often criticised for their preoccupation with sophisticated multivariate models, and for failing to establish the nature and qualities of their data. A difficulty in this regard is that the most frequently used quantitative models, including multiple and logistic regression and discriminate function analysis, are parametric techniques that assume variables to be normally distributed. This may not reflect actual conditions (Rose and Altschul 1988: 182-183). Classic spatial analysis has also been criticised for failing to acknowledge the contextual information that is of potential value in the recognition of complex patterns (Kintigh and Ammerman 1982: 33-34). The deterministic paradigm that underlay many early experiments in 'spatial archaeology' is now widely seen as overly reductionist, and as underestimating the cultural complexity of past human societies (e.g. Gaffney and van Leusen 1996, Witcher 1999).

Population densities have been variously estimated for Near Eastern settlements by different researchers. Wilkinson et al (1996) suggests that lower and upper estimates of 100 and 200 persons per hectare are likely to bracket the actual past population densities at settlement mounds (Wilkinson et al 1996: 21). Yakar has estimated the population of a 1 - 2 acre (0.4 - 0.81 hectare) Anatolian village during the late fourth to early third millennium BC at between 150-200 persons (Yakar 1985: 37), a mid-range value of 290 persons per hectare. Adams estimates population density at 200 persons per hectare of town or village settlement area in the Mesopotamian Early Dynastic period, based on a review of the estimates used by other researchers (Adams 1965: 123-124). Russell draws on historical census data for Eski Baghdad to derive a figure of 150 persons per hectare for early urban settlements across the Near East (Russell 1958: 12). Renfrew estimates the population density of Neolithic sites

in the Aegean at *circa* 200 persons per hectare (Renfrew 1972: 94). Angel (1971) estimates the Neolithic population of Çatalhöyük at between 5,000 and 10,000, although Todd suggests the actual figure would be at the lower end of this range (Todd 1976: 123). Mellaart makes a 'conservative' estimate of 5,000 to 6,000 inhabitants at Çatalhöyük (Mellaart 1975: 99), implying a population density of over 300 persons per hectare.

Changing settlement layouts, from the highly nucleated mounds of early prehistory to the more open settlement layouts of the first millennium BC and later, suggest a reduction in the population density of settlements in later periods. Population densities were estimated for the modern villages on the Çarşamba fan using mid-twentieth century census data for the villages of Üçhüyükler, Güvercinlik, Küçükköy, Dedemoğlu and Alemdar (Table 5.1, census data from French 1970a: 148). The approximate residential area (i.e. excluding orchards, gardens, cemeteries and other open areas) of these five villages at around the time the data were collected was digitised from 1:25,000 scale map sheets printed in the early 1960s. The residential area values derived for each village in this fashion are given in Table 5.1 and suggest a figure of about 40 persons per hectare might be a reasonable approximation of recent historic population densities at villages on the Çarşamba fan.

	pop. (1950)	pop. (1965)	area (hectares)	persons/ha.
Üçhüyükler	376	599	17.5	27.9
Güvercinlik	905	1364	31.5	36
Alemdar	542	528	13	41.2
Dedemoğlu	484	379	7.25	59.5
Küçükköy	806	904	19	45
Total	3113	3774	88.25	39*

Table 5.1 Population density at five villages on the Çarsamba fan for the period 1950-1965 (census data from French 1970). Population densities were calculated from the averaged census data divided by the residential area (\* average).

Population estimates based on settlement size are particularly sensitive to any error in determining the diameter of a settlement because of the geometric relationship that

exists between diameter and area. There is also evidence to suggest that settlement size may be a poor proxy for population levels, especially where surface visibility is low or where differentiation in architectural patterns is not apparent. In particular, it is probably unrealistic to assume similar population densities at large and small settlements (Schreiber and Kintigh 1996: 578). Given the sources of error associated with calculating past population levels, it is apparent that population estimates are mainly of comparative, rather than absolute value (Adams 1972).

The extent of the possible sustaining areas required by agricultural settlements have been calculated by Wilkinson et al (1996) for a biennial fallow dry-cultivation regime with an estimated low yield year productivity of 300 - 350 kg./hectare and an individual dietary requirement of 250 kg. of grain or grain equivalent per annum. These figures indicate that a one-hectare field would support one person every second year (Wilkinson et al 1996: 21). Adams estimates 1.4 hectares of cultivated land were needed per person to support Early Dynastic populations on the Diyala floodplain of Iraq (Adams 1965: 42). These figures compare to estimated yields of 50-150 kg./ dönüm (10 dönüm = 1 hectare) for indigenous barleys and hard wheats under dry "wooden-plough" agriculture and cereal yields of 44 and 75 kg./ dönüm on different soils under dry cultivation with 350mm. annual rainfall (Zohary 1969 and Webley 1970, in Hillman 1973b: 227).

Hillman has estimated the yields obtained for different crops and modes of non-mechanised agricultural production using data collected at Aşvan village in Elazig province (Hillman 1973a, Hillman 1973b). Hillman's data suggest mean gross yields (i.e. after winnowing and coarse sieving, but before removal of next year's seed) under low intensity irrigation of 110 kg./ dönüm for hard wheat and 115 kg./ dönüm for barley. These yields contrast with yields of 63 kg./dönüm for soft wheat, and 41 kg./ dönüm for two-rowed barley under dry-cultivation. An additional yield-reduction factor of 9% is applied to account for periodic crop failures or poor harvest years. (Hillman 1973b: 226-227). Hillman estimates 80% of the calorific requirements of the Asvan villagers were derived from wheat products in the recent historical past, equivalent to 320 kg. of un-milled wheat/person/annum (Hillman

In terms of reconstructing patterns of land use surrounding settlements, Hillman found complex patterns of land management among the *Aşvanlılar*, with the intensity of land use varying with distance from the settlement. The most intensive agricultural strategies, including manuring and the cultivation of small irrigated gardens, were generally carried out closest to the settlement while less intensive dry-land fallow land use became dominant at larger distances (Hillman 1973b: 219-220). If the central feature of agricultural production on the Çarşamba fan is assumed to have been the cultivation of wheat/barley under low-intensity irrigation, approximate minimum sustaining areas can be calculated for individual settlements using data such as that provided above. To simplify this calculation, settlements are considered to have a circular form and to be surrounded by concentric field systems containing cereal crops cultivated under a low-intensity irrigation regime.

Hillman's findings at Aşvan imply that a 1.5 hectare hüyük settlement, 140 metres in diameter and housing around 225 persons would require a minimum sustaining area of around 61 hectares under low-intensity irrigation. This area is equivalent to a 380 metre wide concentric band of cultivation beyond the limits of the settlement.

#### 5.4 Analysis of reconstructed settlement distributions

The numbers of settlements on the Çarşamba fan in different archaeological periods are shown in Figure 5.1. The lower number of settlements in the early prehistoric periods may partly reflect recovery bias, as previously discussed in Chapter 2. The scale of the apparent collapse in settlement distributions on the fan in the Early Bronze III and second millennium BC is particularly prominent. These two periods span an interval of perhaps twelve centuries or more, between around 2400 -1200 BC. While archaeological visibility, both in terms of the recognition of cultural material dating to these periods within mixed surface assemblages and the obtrusiveness of settlement themselves, may be a factor in the reduced recovery of EB III and second millennium settlements, visibility factors alone cannot fully



account for the scale of the observed drop in settlement numbers (Mellaart 1963: 236).

As an initial exploration of the spatial characteristics of settlement distributions mean nearest neighbour distances were calculated for different periods using the [near] function available within the INFO-MAP spatial analysis program (Bailey and Gatrell 1995). A second measure of the distance to surrounding settlements in each period, termed proximity 3, was calculated using the cumulative distance to the first three nearest neighbouring settlements. The proximity 3 measure is intended to provide an alternative indicator of probable distance to a neighbouring settlement in any direction. The mean values for these measures and their standard deviations are also summarised by period in table 5.2.

The mean distance to nearest neighbouring settlements provides a measure of settlement intensity that can be readily calculated and compared between periods. Further analyses are possible based on nearest neighbour distances to explore clustering in point patterns but this topic is approached using alternative techniques later in the chapter. The present discussion will be confined to the data in table 5.2. A prominent feature is that the mean distance to a first neighbouring settlement in the second millennium BC is greater than in other periods at over four kilometres. This represents a value more than half as large again as the average distance to a first nearest neighbour over all the periods considered (2.5 km). While there are far fewer sites in the second millennium BC, the Early Bronze and second millennium distributions extend across similar areas but the differences between the settlement distributions of these two periods are obvious from their 'proximity 3' values. The wider spacing of settlements in the second millennium clearly reflects a reduction in population and in the intensity of the land use around settlements, rather than a simple contraction of the settled area.

A reduction in the spacing between settlements was earlier observed between the Hellenistic and the Roman and Byzantine period (Figure 4.4). This characteristic is clearly reflected in the mean nearest neighbour data, and suggests that a densification



of settlement and corresponding increase in the intensity of agricultural land use characterises the interval between the first millennia BC and AD. Settlement spacing is highly regular in the Hellenistic period, as indicated by the low variance of both the first nearest neighbour and proximity measures. The lowest mean distances to first nearest neighbour and proximity values occur in the Roman and Byzantine period, indicating a relatively densely packed settlement. The analysis of aggregate site area data suggests high population levels in this period (Baird 1997: 13).

A final observation with regard to table 5.2 is that the mean distance to a first neighbouring settlement appears remarkably stable in most periods. The range of values is within 0.5 km between the Early Chalcolithic and Roman and Byzantine periods, if the second millennium data is excluded. This feature is unexpected given the different numbers of settlements recorded in each period and their diverse cultural contexts. The relative stability of minimum settlement spacing over such a long period further emphasises the contrast between the settlement distribution seen in the second millennium and those of earlier and later periods.

In an earlier section of the chapter, the limited scope for using covariance techniques to model settlement location decision-making was emphasised. If however the correlation between settlements and different soils units in the modern landscape is considered in terms of the potential impact of alluvial deposition on the recovery of settlement evidence, covariance techniques may provide a useful analytical approach.

It should be stressed that the aim here is not to link the distribution of past settlement activity to the distribution of modern soils through inferences about locational decision-making. This recalls the earlier observation that the various soils units that make up the Çarşamba fan are of different age and derivation. The formation of some soils units clearly predate the earliest archaeological evidence for settlement - e.g. the palaeoshoreline ridge and the sand plain or playa at its eastern end, which are of Pleistocene age, others post-date the settlement activity under examination. It seems certain for example that such analyses will provide more information about preservation and recovery bias than about locational preference in the earliest

periods, as illustrated by the deep post-occupation alluvial deposits in the vicinity of the Neolithic mound at Çatalhöyük. The situation is less clear for more recent periods. The lack of an independently dated formation chronology for the fan means that the formation of some units may be coeval with, earlier, or later than, specific settlement distributions. This issue of identifying the physical environments contemporary with specific past settlement distributions affects both archaeological and geomorphological research on the fan.

Although the archaeological dating framework contains large blocks of undifferentiated time it potentially offers better resolution than any chronology that has yet been developed using geological methods. Linking the age of individual soils units to specific archaeological periods is therefore a way to date the Holocene geomorphology of the fan. The archaeologist is as interested in reconstructing information about past physical environments during specific periods as the geomorphologist is in dating a specific sedimentary unit and so there is scope for collaboration between the two areas of research.

It is important that the past physical environments of the Çarşamba fan are not viewed as a series of static states. Alluvial fan environments have been described as highly dynamic settings, subject to rapid change and considerable environmental variability is indicated in the geomorphological sequence of the Çarşamba fan. In the period since the Late Glacial Maximum, this has included periods of widespread over-bank sedimentation, semi-permanent inundation and of alluvial hiatus accompanied by the entrenchment of stream channels. This variability in the local environment would impact human populations on the fan and may be reflected in past settlement distributions.

In the following analysis, the settlement distributions reconstructed for different periods are compared to the distribution of the various soils units on the fan. The aim of the analysis is to establish if any relationship can be identified between the pattern of settlement evidence and the distribution of the younger backswamp soils and Çarşamba alluvium, the most recent soils units laid down on the fan.

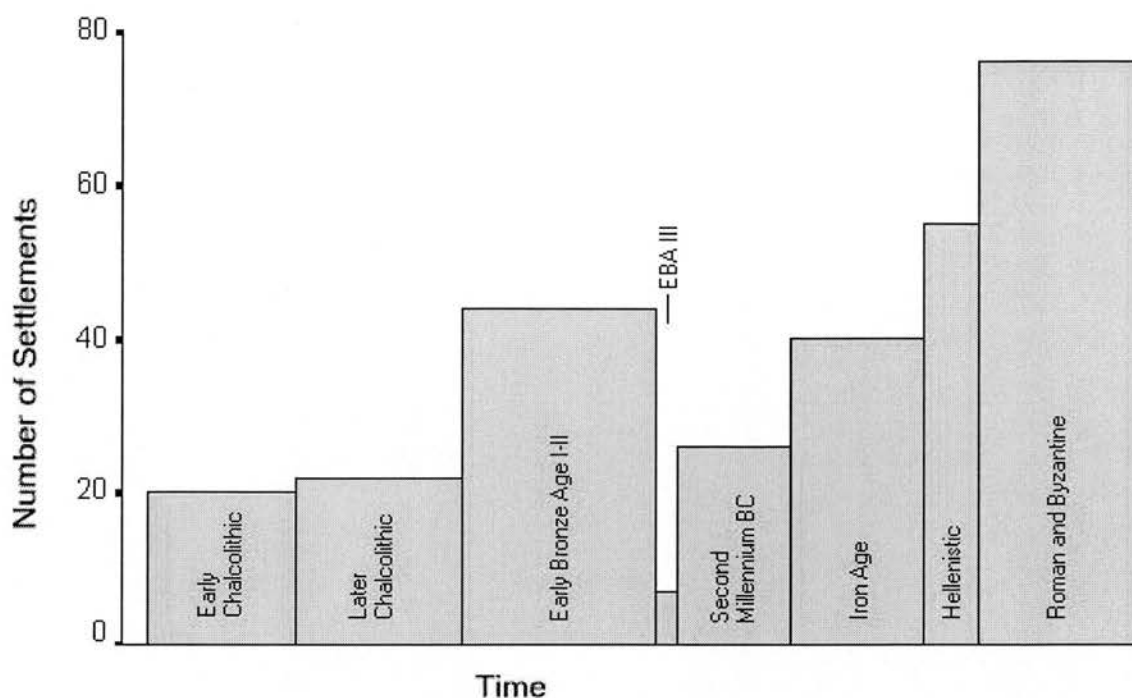


Figure 5.1 Graph showing number of settlements and relative duration for different archaeological periods.

	N	nn1 mean	std. dev.	proximity 3 mean	std. dev.
Early Chalcolithic	20	2144	711	11158	2634
Later Chalcolithic	22	3047	1968	11846	5225
Early Bronze I-II	44	2849	1343	5687	2513
Second millennium	26	4219	2247	33389	93069
Iron Age	40	2584	1289	10000	4570
Hellenistic	55	2525	925	10018	2931
Roman and Byzantine	76	2151	958	8336	2838

Table 5.2 Mean distances (metres) to first nearest neighbour and mean cumulative distance to three closest settlements (proximity 3) in different periods.

For the purpose of examining the distribution of settlements with respect to specific soils, the detailed classification set out for the Çarşamba fan by de Meester (1970) is generalised to seven categories as follows; (1) backswamp soils (2) fine alluvium soils (3) levee / channel soils (4) sand plain or playa soils (5) younger backswamp soils (6) sand ridge and beach soils (7) aeolian clay ridge soils. The percentage of the total study region classified to each soil group is as follows; (1) 44% (2) 33% (3) 6% (4) 6% (5) 5% (6) 4% (7) 2%. Using these figures and the total number of settlements in each archaeological period, the expected frequency of sites can be calculated for each soils group and compared against the frequency observed.

The significance of the site frequencies in table 5.3 can be investigated further using the chi-square statistic;

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

, where  $O$  is the observed, and  $E$  the expected number, of cases in each category (Gregory 1978: 119).

From the data in table 5.3 the observed frequency of settlements of all periods on the beach ridge soils can be seen to be higher than expected. This pattern is perhaps explained by the natural advantages of the elevated and well-drained beach ridge as a location for settlement in a landscape subject to periodic inundation. The use of the beach ridge formation as an elevated causeway running east to west, and providing a natural fording place on the Çarşamba at Seyithan, would also provide a focus for settlement along this feature.

The younger backswamps and fine alluvium are believed to have formed as the result of over bank flooding since the Early Bronze Age and the analysis of settlement frequency figures for these soils might provide a more precise indication of the date that these soil units were formed. Instead, the observed frequency of settlements is close to the expected value throughout the period when it is believed their formation was taking place. Raised settlement frequency is found on these soils during the

Early Chalcolithic and also in the Roman and Byzantine period, where the observed frequency is significantly higher than expected (Table 5.3). This suggests that the areas containing these soils in the modern landscape were treated no differently to other parts of the fan for settlement purposes throughout much of the period when they are believed to have been actively forming. The higher frequency of settlement in the Early Chalcolithic is difficult to interpret as it clearly predates the formation of the modern soils units in these areas and must relate to some earlier aspect of the landscape. In the Roman and Byzantine period there is a clear preference for these soils and this, together with evidence for re-settlement of the central fan generally, suggests that areas of higher soil moisture were favoured for settlement.

The frequency of settlements located on sandplain soils is lower than expected from the Early Bronze Age I and II period onward, perhaps a reflection of the poorer agricultural potential of these soils compared to other soils on the fan. This feature is especially prominent in the Iron Age, Hellenistic and Roman and Byzantine periods. With respect to the distribution of Hellenistic settlements, a further remarkable feature is the similarity between the observed settlement frequency across the different soils groups and that expected within a uniform distribution. The earlier impression of a highly regular settlement pattern, suggested earlier by the low variance in first nearest neighbour distances, is reinforced (Table 5.2).

The pattern of occupation in successive archaeological periods may provide additional information that is of value in the interpretation of past settlement distributions. Differences are apparent in the distribution of single period and multi period settlements. The distribution of multi-period settlements at which there is evidence for four or more settlement phases is shown in figure 5.2.

Mellaart (1961) has proposed that there is a settlement shift on Konya Plain between the Early Chalcolithic and Later Chalcolithic periods. Less than half of the Early Chalcolithic settlement locations are occupied during the Later Chalcolithic and the abandonment of the most prominent Early Chalcolithic settlement at Çatalhöyük west is a notable feature of the transition between the two periods.

soils unit	E Chalco		L Chalco		EBA I-III		2 <sup>nd</sup> Mill BC	
	observed	expected	observed	expected	observed	expected	observed	expected
1	9	7.92	12	7.92	15	16.29	9	9.24
2	2	5.9	4	5.9	15	12.12	7	6.88
3	0	1.05	0	1.05	2	2.16	0	1.23
4	1	1.01	1	1.01	0	2.07	0	1.17
5	3	0.93	0	0.93	2	1.91	1	1.08
6	3	0.79	2	0.79	3	1.63	3	0.92
7	0	0.40	0	0.40	0	0.82	1	0.47

soils unit	Iron Age		Hellenistic		Rom-Byz	
	observed	expected	observed	expected	observed	expected
1	17	13.65	21	21.13	26	27.29
2	9	10.16	18	15.73	25	20.32
3	0	1.81	0	2.81	1	3.63
4	0	1.73	0	2.68	1	3.47
5	2	1.6	2	2.47	0	3.19
6	3	1.36	6	2.11	7	2.73
7	0	0.69	1	1.07	2	1.38

Table 5.3 Observed and estimated frequencies of settlements in different areas of the Çarşamba fan.

The pattern of settlement development in later periods is very different to that observed between the Early and Later Chalcolithic. The nature of the transition from the Later Chalcolithic into the Early Bronze Age I and II period is overshadowed by the two-fold increase in the number of settlements and by the appearance of a marked site-size hierarchy. Around half of Later Chalcolithic settlement locations continue to be occupied during the Early Bronze period. Continuity of occupation is more evident in the Iron Age through Roman and Byzantine period, especially between the Hellenistic and Roman and Byzantine settlement distributions.

The archaeological materials collected during archaeological survey are evidence of an areal or extensive phenomenon, the occupation of ancient land surfaces by successive human populations. By contrast, the data from which a picture of past human occupations must be reconstructed are generally recorded at discrete locations, e.g. the surfaces of ancient settlement mounds, rather than continuously across the surface of the landscape. Some method for the interpolation or projection of continuous surfaces from survey data is required (Robinson and Zubrow 1999).

Quadrats or cell counts are often used in quantitative spatial archaeology to transform point distributions into continuous data, usually as an initial step in spatial analysis (e.g. Chadwick 1978, Kvamme 1988, Shennan 1992). A limitation of this approach is that the range of possible cell size that can be used is limited by the need to retain the spatial detail of the original distribution. The structure of the variance in cell count distributions is also sensitive to cell size, a phenomenon termed the modifiable areal unit problem (Fotheringham and Wong 1991).

Logistic trend surfaces produced using higher order polynomial functions may also be fitted to the archaeological settlement locations recovered by field survey as a convenient method of generating continuous settlement probability estimates across a region (e.g. Warren 1990a, Kvamme 1988). A difficulty with this use of logistic regression surfaces is that the statistical preconditions for modelling spatial variation in site location as a global trend through the calculation of logistic trend surfaces are unlikely to be met in archaeological datasets. Standard regression assumes



independent random errors within the data. The tendency for real world spatial processes to exhibit some degree of spatial dependence is well documented in the spatial statistics literature (e.g. Cressie 1991). Where data are spatially dependent, the residuals produced by regression will be similarly correlated as a result of the presence of multiple sources of spatial variation within the observed distribution.

Even where the use of regression is limited to the informal interpolation of trend surfaces from archaeological settlement data, the results are likely to provide poor local predictions of settlement location. The global smoothing produced by polynomial functions will tend to remove local detail that may be important to properly characterise settlement location. A further undesirable characteristic of regression surfaces is their sensitivity to outliers and observational errors, which will influence the fit to the data across the entire regression surface.

The significance of apparent increases in 'gain' or skill in such models should be treated with caution, especially where these are obtained through the use of higher order polynomials (e.g. Kvamme 1988: 341-344). As higher order terms are applied, the resulting regression coefficients become highly correlated and correspondingly unstable. As a consequence, the fitted surface is increasingly sensitive to outliers and observational errors (Bailey and Gatrell 1995: 170-171). While higher order (e.g. cubic) mathematical functions produce an improved fit with the sample data, the resulting model may deviate markedly from the trend of the wider population if used as an extrapolator. A similar situation arises in the geometric correction of image data from ground control coordinates, where higher order polynomials produce a better fit in the vicinity of control points at the cost of significant distortion in other regions of the image (Richards 1993: 60-61).

The alternative technique of kernel intensity estimation has some advantages over the fitted logistic trend surfaces frequently used to characterise archaeological distributions (e.g. Kvamme 1996: 33). Kernel density estimates do not rely on regression techniques and can be used where data are non-normally distributed. Kernel estimates are also relatively robust with regard to variations in size and shape

of the study area, or  $R$ . This is an advantage in the present analysis where the limits of the study region (i.e. the extent of the cultivable soils contemporary with the settlement distribution under investigation) cannot be reliably determined. The use of kernel intensity estimates avoids the need to closely estimate  $R$ , allowing a comparison of settlement intensity estimates in different periods. A range of bandwidth values can then be explored interactively using kernel density estimates.

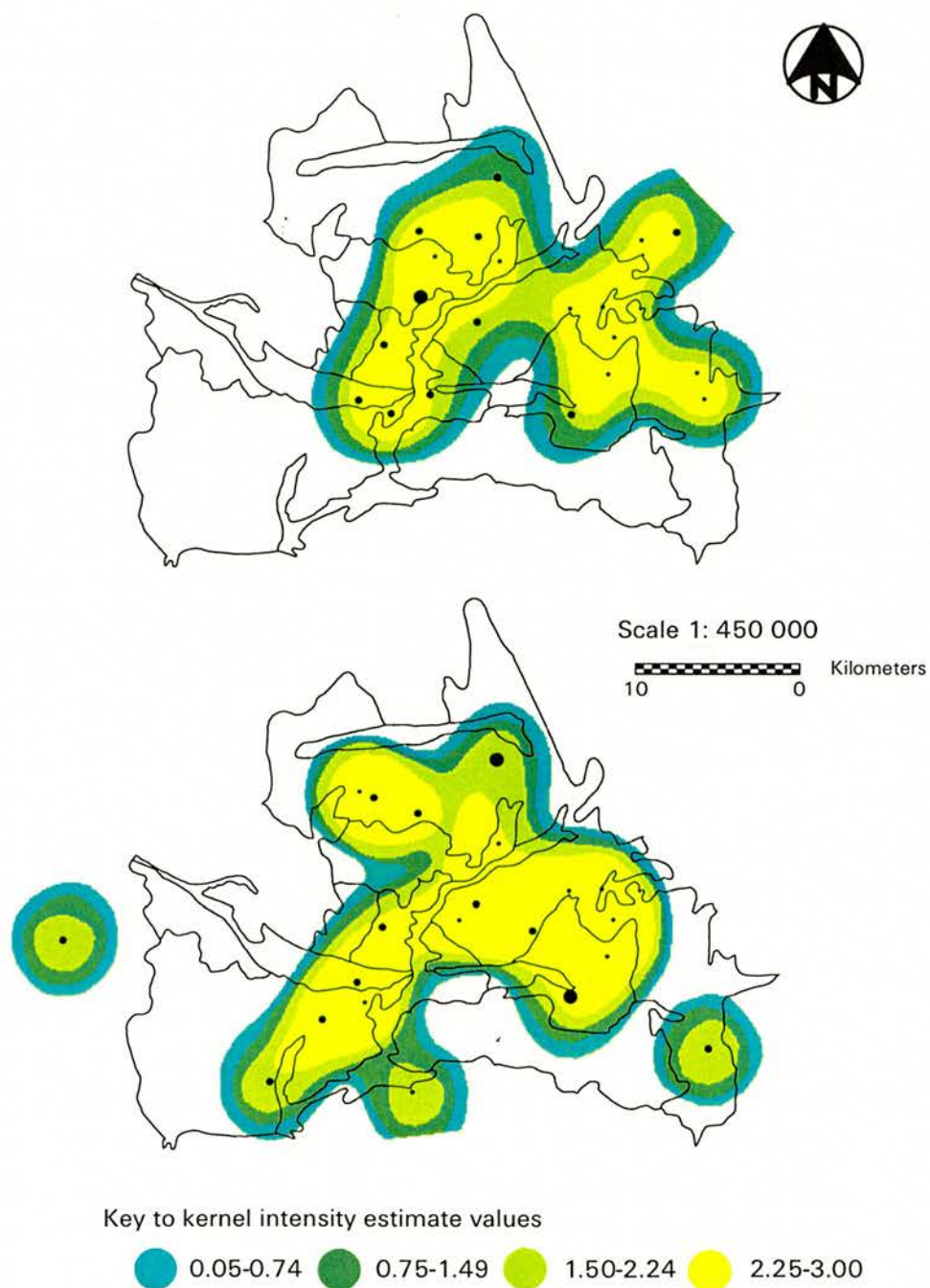
Kernel intensity estimates offer a robust alternative to the use of trend surfaces, particularly in archaeological studies where settlement location is investigated in the absence of environmental variables and where the available data are likely to be incomplete or of locally variable quality. The ability to vary the bandwidth of the kernel intensity calculation independently of cell size is an advantage of this approach.

If  $s$  represents a general location within a study region  $R$ , and  $s_1, \dots, s_n$  are the locations of  $n$  observed events, intensity  $\hat{\lambda}_\tau(s)$  at  $s$  can be calculated using;

$$\hat{\lambda}_\tau(s) = \sum_{h_i \leq \tau} \frac{3}{\pi\tau^2} \left(1 - \frac{h_i^2}{\tau^2}\right)^2$$

, where  $h_i$  is the distance between point  $s$  and the observed event location  $s_i$  and summation is restricted to values of  $h_i$  which do not exceed bandwidth  $\tau$ . Observed events contribute to intensity within a circle of radius equivalent to the selected bandwidth  $\tau$ , centred on  $s$ . The function is scaled using a factor of  $\tau$  with the weighting at  $s$  (i.e. at distance zero) being  $3/\pi\tau^2$ , decreasing smoothly to a zero at distance  $\tau$ . By performing this calculation at all event locations (i.e. settlement centroids) within the distributions a kernel intensity estimate is created which provides an indication of the local intensity of interaction between settlements in different regions of the study area.

The kernel density estimates (Figures 5.2 through 5.5) were generated using the kernel function within INFO-MAP to explore variations in settlement density across the fan at different scales, with emphasis on the level of potential spatial interactions



5.2 Kernel intensity estimates for Early Chalcolithic period settlement (top) and Later Chalcolithic period settlement (lower) calculated using 5 km. bandwidth.

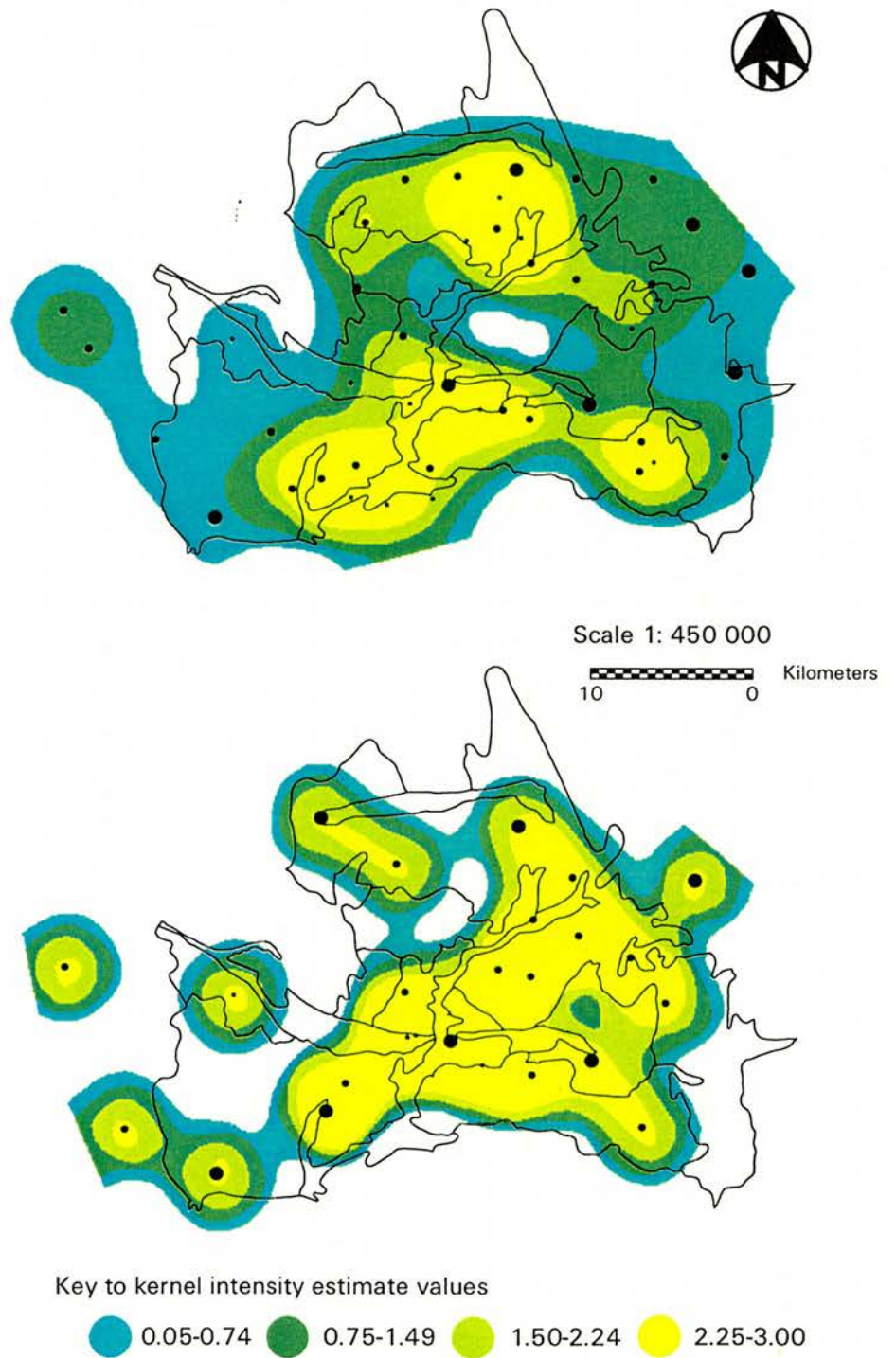


Figure 5.3 Kernel intensity estimates for Early Bronze I-II period settlement (top) and Second Millennium BC (lower) calculated using 5km. bandwidth.



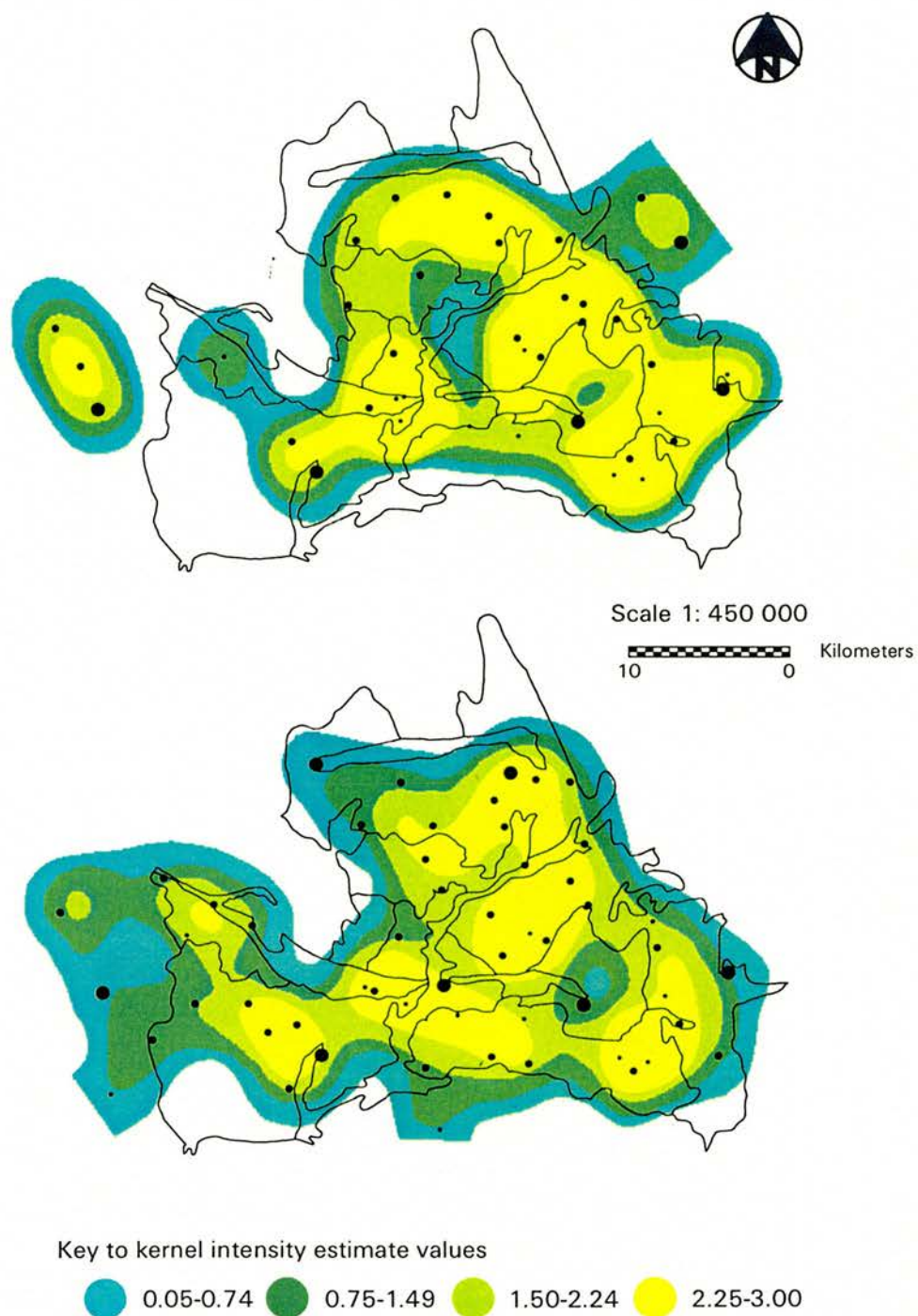


Figure 5.4 Kernel intensity estimates for Iron Age period settlement (top) and Hellenistic period (lower) calculated using 5 km. bandwidth.

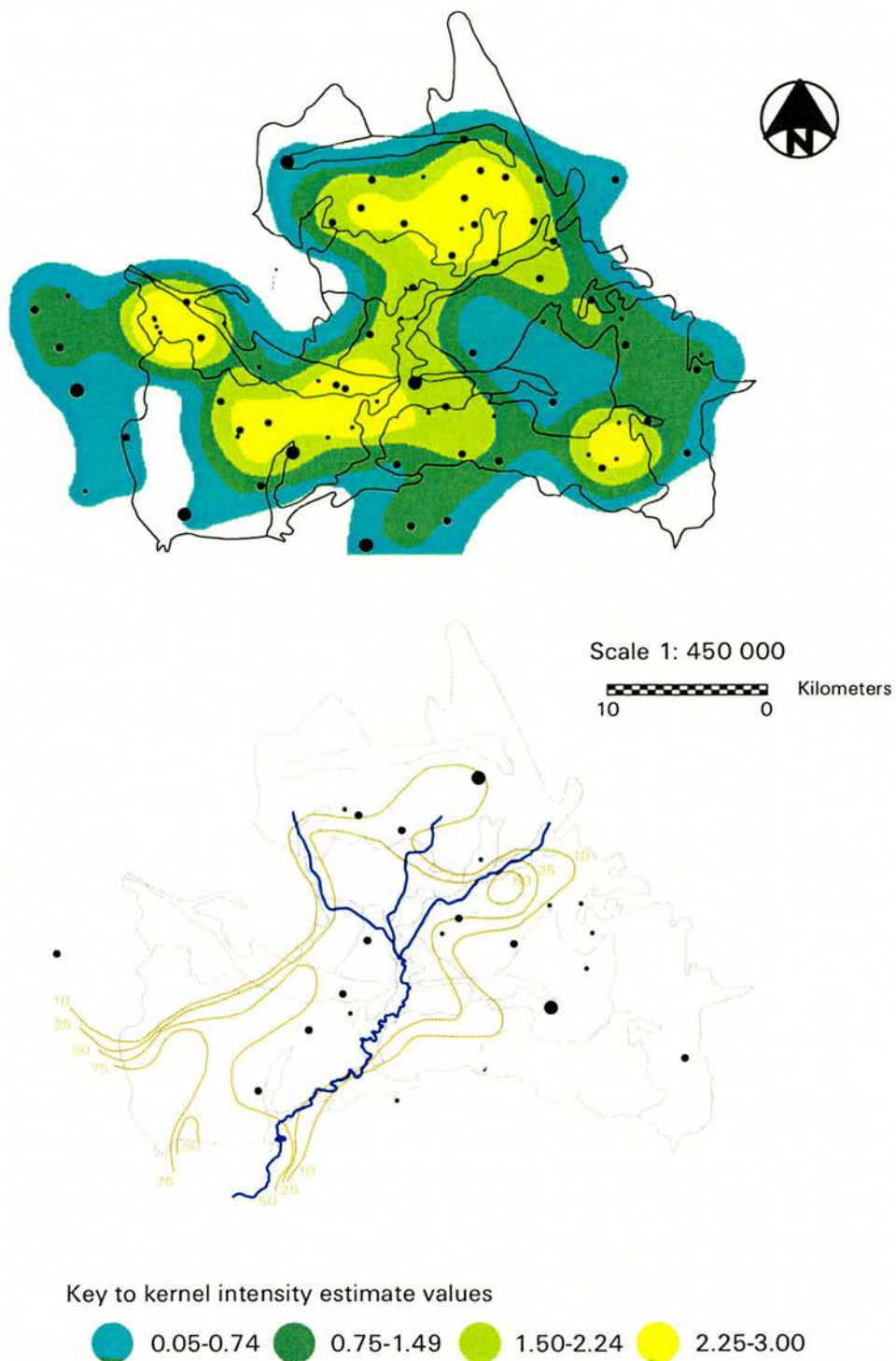


Figure 5.5 Kernel intensity estimate for Roman and Byzantine period settlement (top) calculated using 5 km. bandwidth. Relationship between Later Chalcolithic settlement distribution, percentage sand present in upper 20 metres of sediment and the modern course of the Carsamba river (lower).

occurring at relatively small scales. The use of kernel intensity estimates provides an improved visualisation over the dot maps of the previous chapter as it produces a measure of the local density of settlement that can be compared between different localities or time periods. Bandwidth values for the analysis were chosen interactively by varying values input to the kernel function until a bandwidth was obtained which was judged to provide an effective smoothing of the data while retaining key features of the original distribution.

When settlement activity from all periods is plotted into a single coverage, the resulting wedge shaped distribution approximates the area of modern fan soils and is oriented along the southwest to northeast axis of the main channel of the Çarşamba Cayı . The intensity of past settlement activity from all periods on the Çarşamba fan generally decreases with distance from the central fan towards its distal limits. A localised exception to this pattern is found in the area north of Seyithan Hüyük. Areas of soft lime soils west and southeast of the fan appear not to be settled in any period (French 1970a). The western limit of past settlement activity on the fan is more sharply defined than its eastern edge, where the spacing between settlements increases in a graded fashion.

An apparent expansion in the overall extent of the settled area of the fan can be identified extending from the Early Chalcolithic into the Early Bronze period (Figures 5.2 and 5.3). The main features of this expansion are the clustering of Early Chalcolithic settlements towards the fan apex, followed by a more extensive Later Chalcolithic distribution, consisting of larger numbers of locations spread over a more extended area. The apparent extension of the settled area of the fan in the Later Chalcolithic is particularly evident to the north and south of the Early Chalcolithic distribution, but excludes some localities settled in the Early Chalcolithic. A notable difference in this regard is the absence of Later Chalcolithic settlement in areas classified as younger backswamp soils in the modern landscape. This feature does not appear to be an artifact of the loss of evidence beneath subsequent alluvial sediment, as it is the later sites that are absent. It may however be significant that the evidence for Early Chalcolithic settlement in this area occurs as a component of the



multi-period assemblages recovered from relatively large mounds. The possibility that small, single period settlements dating to both the Early and Later Chalcolithic may lie buried beneath later alluvium in this area cannot be excluded.

Regions of higher intensity settlement occur in the northern and western fan during the Early Bronze Age I and II period. A further feature of settlement patterning in this period is the appearance of a linear arrangement of settlements extending from the central fan towards its south-eastern limit, south of the shoreline ridge. The appearance of this line of settlements in an area where (with the exception of Sarlak Hüyük) there is no evidence for Later Chalcolithic settlement may indicate the presence of a channel of the Çarşamba running east from the centre of the fan towards the Hotamış area during the Early Bronze period.

Cohen plots the distribution of prehistoric sites in relation to the percentage of sand in the upper 20 metres of Çarşamba river deposits and cites evidence to suggest an ancient branch of the Çarşamba river once extended to the east of Çumra towards the Hotamış depression (Cohen 1970: 135). An 'exceptional grouping' of settlements identified in the eastern fan by Cohen contains both Early Bronze I and II and Hellenistic settlements, suggesting perhaps that a stream channel may have passed through this area in both periods. In the Later Chalcolithic, a group of settlements within the intensively settled region to the south of the shoreline ridge form a conspicuous linear arrangement to the west of the present course of the Çarşamba, perhaps also indicating the course of a former channel. A map of sand percentages in the sediments of the fan is reproduced in Figure 5.5 alongside the Later Chalcolithic settlement distribution and modern course of the Çarşamba.

Low-density regions in the Early Bronze Age settlement distribution occur in the younger backswamp soils of the western fan and along the Çarşamba Çayı towards the north-eastern fan in the vicinity of Ovakavağı village. Both these areas are poorly drained and contain moderately salt-affected soils in the modern landscape (de Meester and Driessen 1970). It seems possible that these areas may also have been poorly drained in the Early Bronze period to an extent that made them less

favourable for settlement.

In the Iron Age there appears to be a change of locus for populations on the fan, with a cluster of new settlements appearing to the south of Karkin village. The intensity estimate in Figure 5.4 shows a region of reduced settlement density in the central fan corresponding to modern channel of the Çarşamba directly north of the breach in the shoreline ridge. This feature is of interest because of the previous observation that the formation of the younger backswamp soils and fine alluvium may have occurred during the Iron Age. An elongated area of reduced settlement density to the north of the shoreline ridge may indicate the avoidance of this area because of flooding. A second region of reduced settlement density is centred on the sandplain soils east of the beach ridge. The south-eastern fan is more densely settled in the Iron age than in any preceding period.

Settlement in the Hellenistic period is both more extensive and more intensive than in the preceding Iron Age, although retaining a number of the same characteristics. The south-eastern fan continues to be an important sub-locus for settlement while the north-eastern fan is intensively settled for the first time, with the appearance of three new settlements in this period. The region of low-density settlement in the central fan during the Iron Age has been filled by occupations at Seyithan Hüyük, Halaç Hüyük and Kuşlu Hüyük I. The sandplain area to the east of the shoreline ridge is again unoccupied in this period.

Roman and Byzantine settlement is noticeably concentrated towards the centre of the fan, with sub-loci on the bajada to the south and west, and in the south-eastern fan in the vicinity of Üçhüyük village. A large area of the central eastern fan, east of the shoreline ridge is unoccupied in this period. By contrast, the northern area of the fan is densely settled, with the continued occupation of former Hellenistic settlements and the appearance of new settlements. New settlements also appear in the bajada areas to the south of the fan.

The kernel intensity estimates discussed above indicate features of past settlement

distributions which require further analysis. Measures of clustering and inter-settlement separation within each period are potentially of some value in the interpretation of these features. In particular, patterns of spatial persistence, indicating second order interaction between settlements, can be identified through the analysis of  $K$  function values. These aspects of past settlement distributions on the fan are now investigated.

Further quantitative characterisation of the clustering of settlement locations of the fan was obtained through the use of  $K$  functions calculated for each settlement distribution. Kintigh and Ammerman (1982) note that an advantage of the  $K$  function as a cluster analysis technique is that it operates directly without the need to use a similarity matrix. This characteristic may be significant in the analysis of reconstructed settlement distributions where data may not conform to the theoretical distribution assumed by some analytical methods, and are likely to be incomplete or contain errors. The  $K$  function can be defined as the expected number of events within a distance  $h$  of an arbitrary event, divided by the mean number of events per unit area, or intensity  $\lambda$ , which is assumed to be constant throughout the study region  $R$  (Bailey and Gattrell 1995: 124).

The  $K$  function can be defined as the expected number of events within a distance  $h$  of an arbitrary event, divided by the mean number of events per unit area, or intensity  $\lambda$ , which is assumed to be constant throughout the study region  $R$  (Bailey and Gattrell 1995: 124).

Where the expected number of events in study region  $R$  is  $\lambda R$ , the expected number of ordered pairs of events at maximum separation  $h$  from a first event in  $R$  is given by  $\lambda^2 RK(h)$ . If the value of unknown intensity  $\lambda$  is estimated using  $\lambda = n / R$  (the number of cases divided by area of the study region) a formula for the estimation of edge corrected  $K(h)$  may be written;

$$\hat{K}(h) = \frac{R}{n^2} \sum_{i \neq j} \sum \frac{I_h(d_{ij})}{W_{ij}}$$

, where  $d_{ij}$  is the distance between the  $i$ th and  $j$ th observed events in  $R$  and  $W_{ij}$  is the proportion of the circumference of a circle centred on event  $i$  which lies within  $R$  - effectively the conditional probability that an event is observed in  $R$  at a distance  $d_{ij}$  from the  $i$ th event. This allows estimated  $K(h)$  to be derived for incompletely mapped point event distributions where the mean number of events per unit area (or intensity)  $\lambda$  is unknown (Bailey and Gatrell 1995: 92-93). Note however that because  $\lambda$  estimated using  $\lambda = n / R$  is sensitive to variation in  $R$ , the same study area parameters should be maintained where  $K$  functions are compared.

Where the  $K$  function is applied as an exploratory device to investigate spatial dependence structures the spatial relationships of reconstructed past settlement distributions can be compared with those of simulated distributions having specific spatial properties for interpretation purposes. The expected number of events within distance  $h$  of a randomly chosen event within a 'random' spatial distribution would be  $\pi \lambda h^2$ , so that  $K(h)$  is equivalent to  $0h^2$  for a homogenous process. As a result of this relationship  $K(h)$  is expected to be less than  $0h^2$  under conditions of regular spacing between events and greater than  $0h^2$  where there is clustering.  $K(h)$  may be compared with  $0h^2$  using a plot of  $L(h)$  against  $h$  where;

$$L(h) = \sqrt{\frac{K(h)}{\pi}} - h .$$

$K$  function distributions were produced for mound locations in each archaeological period. This was not done for the early prehistoric and Early Bronze Age III settlement evidence because the reconstructed settlement distributions for these periods were considered to tentative and incomplete for this type of analysis.

In Figure 5.6, plots of  $L(h)$  vs  $(h)$  are calculated from reconstructed settlement

distributions using the 5 km bandwidth previously applied to create kernel density estimates. This 5 km bandwidth value was chosen on the basis of inspection of first and higher order nearest neighbour profiles generated for the reconstructed distributions and partly summarised in Table 5.2. As  $K$  functions were being used to investigate the nature of spatial interaction between sites and their immediate neighbours in different periods, a relatively small bandwidth value was used to ensure that the proximity to nearest neighbouring settlements was considered while excluding possible clustering at larger scales. For each settlement period, the results are displayed against significance envelopes generated from multiple simulated distributions conforming to a complete spatial randomness (CSR) model. In each instance 100 simulated distributions containing the same number of settlements as the original settlement distribution were used to derive upper and lower envelope values.

Positive peaks, where plotted  $L(h)$  vs  $h$  crosses upper envelope indicate elevated levels of clustering at specific inter-settlement spacings, compared what would be expected under conditions of complete spatial randomness (CSR). While the  $K$  function distribution profiles vary between settlement periods, a common feature is increased clustering at inter-settlement separations of around 2.5km. This structure is found in each of the periods studied, except the second millennium BC. Other notable features of the  $K$  function analyses results are a second peak between 4km and 4.5km, found in the Later Chalcolithic, Iron Age, Hellenistic and Roman-Byzantine settlement distributions, and evidence for clustering at around 1.5km in the Early Chalcolithic, Later Chalcolithic and Iron Age settlement.

While no distinct patterning is apparent from the  $K$  function analysis of Later Chalcolithic settlements, peak values for mapped occur at settlement spacings of between 3.0 km. and 3.5 km. (figure 5.8). This is rather larger than the 2.0 km. to 2.5 km. found during the Early Chalcolithic and, together with the increased number of settlements, is reflected in the greater extent of the Later Chalcolithic settlement distribution.  $K$  function analysis of the mapped Early Bronze Age I and II settlement distribution indicates clustering at inter-mound distances of 2.1 and 2.8 km.

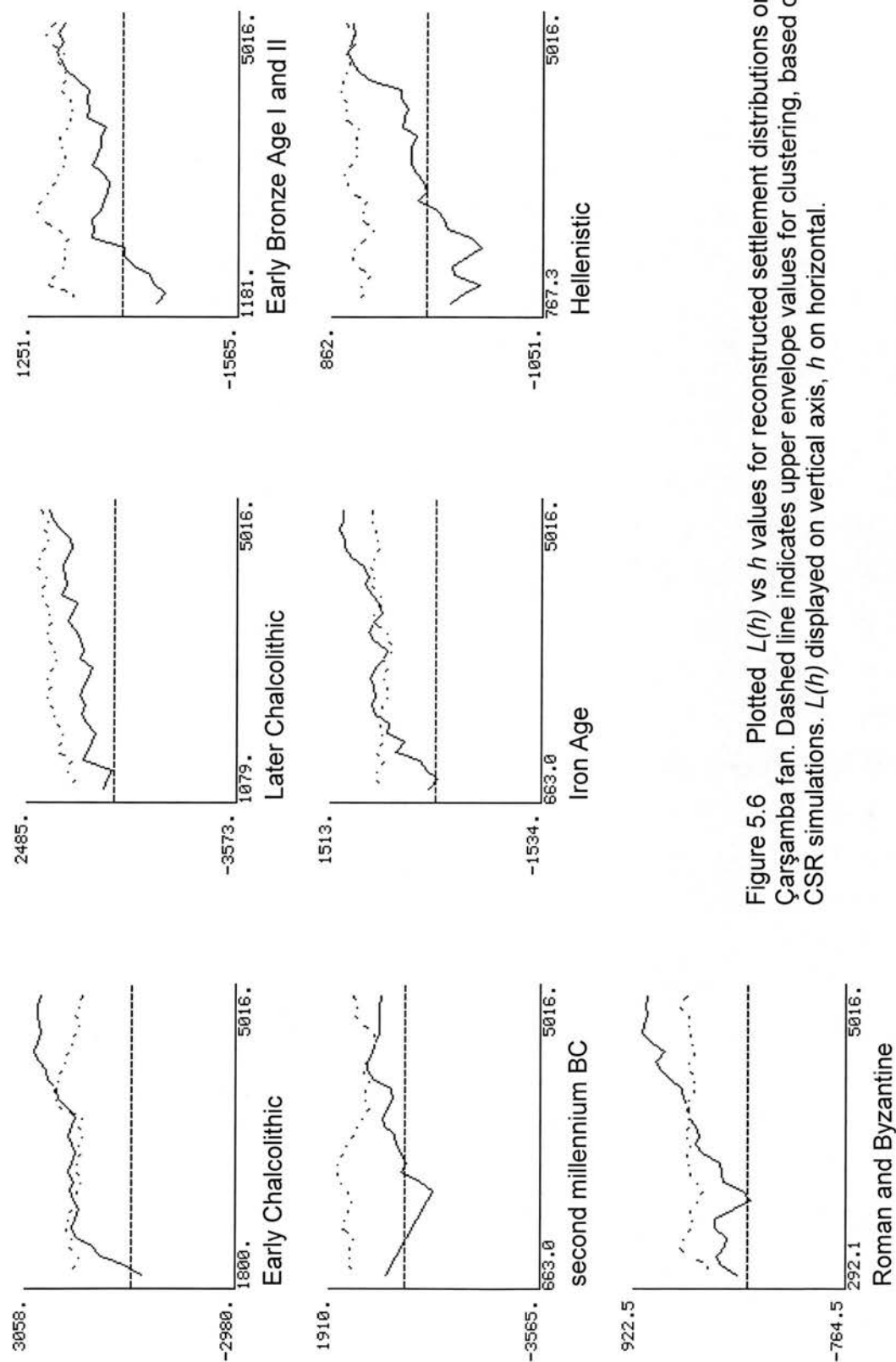


Figure 5.6 Plotted  $L(h)$  vs  $h$  values for reconstructed settlement distributions on the Çarşamba fan. Dashed line indicates upper envelope values for clustering, based on multiple CSR simulations.  $L(h)$  displayed on vertical axis,  $h$  on horizontal.



The position of peaks above the upper multiple CSR simulation threshold indicates that this pattern is unlikely to occur randomly. Clustering at these inter-mound distances is interpreted as a significant feature of the Early Bronze Age I and II settlement distribution. The analysis of settlement spacing during the Iron Age period using *K* functions shows clustering at spacings between 1.7 km. and 2.0 km. The Hellenistic settlement distribution *K* function shows elevated values above 4.0 km. Peak *K* function values in the Roman and Byzantine period occur at spacings greater than 2.5 km.

Peak *K* function values occur within similar ranges in different periods, a result which supports the finding made earlier in connection to mean nearest neighbour values. Patterns of settlement spacing in different periods appear to reflect some dynamic that is operating across different temporal and cultural contexts.

### 5.5 Summary

The methods used to investigate archaeological settlement distributions are required to be more robust than those that might be applied to investigate modern settlement distributions because of the nature of archaeological data. The objective of this chapter has been to attempt an exploratory data analysis approach to the settlement distributions reconstructed for different periods on the Çarşamba fan. Several types of analysis were used to identify and describe the major characteristics of settlement distributions. Non-parametric statistical methods have been preferred because the settlement distributions reconstructed from archaeological evidence are considered likely to be both incompletely mapped and subject to differential recovery. Nearest neighbour distances, the chi-square statistic, kernel intensity estimates and *K* function analysis were applied to reconstructed settlement distributions in order to explore their spatial characteristics.

Past settlement distributions were investigated as spatial processes subject to first order and second order influences on location. The western fan has been an attractive location for settlement in all periods and contains settlements with the longest settlement records. By contrast, the eastern fan has experienced episodic settlement

and abandonment. The eastern fan is most densely settled in the Early Chalcolithic, Iron Age and Hellenistic periods. The central fan is intensively occupied in the Early Chalcolithic and Roman and Byzantine periods, by contrast to the sparse settlement of this area during the Early Bronze Age I and II period. In terms of secondary influences on settlement, the mean spacing between a settlement and its first nearest neighbour has remained remarkably stable over time, having a value of around 2.5 km.

## Chapter 6: Remote Sensing and Archaeological Prospection

### 6.1 Introduction

The objective in using remote sensing technology on the Çarsamba fan is to increase the visibility of the archaeological settlement record, particularly of those less obtrusive components of the settlement record of the fan that are likely to be overlooked by conventional field survey. Examples of unobtrusive settlement remains include past settlement sites located away from modern roads and tracks, 'flat' sites or surface scatters and sites of small area.

### 6.2 Terminology

Within archaeology the term 'remote sensing' is used to describe a range of methods and techniques for the detection of archaeological features (e.g. Scollar et al 1990). These methods include aerial photography (Crawford 1954, Ebert 1988), spaceborne remote sensing (Scollar et al 1990), and ground-based geophysical and geochemical prospection methods, such as magnetometry, soil resistivity, ground penetrating radar and phosphate analysis (Clark 1990, Scollar et al 1990). In the context of the present project, the term remote sensing is used to describe "...the gathering and processing of information about the Earth's environment, particularly its natural and cultural resources, through the use of photographic and related data acquired from an aircraft or satellite." (Colwell 1983: 1) and "... the non contact recording of information from the electromagnetic spectrum by means of mechanical, photographic, numeric, or visual sensors located on mobile platforms." (Fussell et al 1986: 1510).

Active remote sensing technologies, such as active radars, which both generate and detect their own source of radiation, are distinguished from passive remote sensing technologies which record electromagnetic energy of solar or terrestrial origin (Mather 1987: 11). Passive remote sensing data acquired by the Landsat Thematic Mapper (TM) and the Systeme Probatoire d'Observation de la Terre (SPOT)

Panchromatic sensors are used to investigate potential archaeological survey applications in the present project. The Landsat Thematic Mapper (TM) data are multispectral, i.e. record energy in a series of wavelength ranges, termed channels or bands. In the case of the TM sensor, seven data bands are recorded across the visible, reflective infrared, middle infrared and thermal infrared regions of the spectrum (Laur et al 1997).

The term digital image processing is a general description used to describe the manipulation of digital image data by machine methods. Examples of digital image processing operations include image enhancement, rectification and multispectral classification.

Procedures for archaeological remote sensing projects are set out by Lyons and Avery (1977), Donoghue and Shennan (1988) and Ebert (1988), although the rapid pace of continuing developments in remote sensing data distribution and software tools suggest that some flexibility is useful in the planning of longer term projects. A brief review of archaeological remote sensing follows to provide a context for the remote sensing work done on the Çarsamba fan.

### 6.3 Aerial archaeology and remote sensing

Archaeologists have been interested in the possibilities of aerial viewing platforms for more than a century. The first systematic aerial archaeology is attributed to Colonel G.A. Beazeley, an officer in the Royal Engineers who became interested in aerial archaeological survey whilst on active service in Mesopotamia during the First World War (Ebert 1984: 300). Beazeley's discovery of ancient irrigation canal networks while flying over Eski Baghdad and his subsequent ground investigations established a methodology that would be familiar to modern aerial archaeologists (Beazeley 1919, Beazeley 1920).

The archaeologist and former Royal Flying Corps observer O.G.S. Crawford pioneered the development of aerial archaeology as a systematic survey technique between the two world wars. Among his other achievements, Crawford was among the first to recognise the possibility of mapping from the air the ephemeral but distinctive parch marks produced in crops grown above archaeological features (Crawford 1923, Deuel 1969). By the mid 1940s, much of the methodology of contemporary aerial archaeology had been established (Wilson 1982, Riley 1987). Conventional aerial photography remains the most widely applied remotely sensing technique in archaeology outside the ground-based prospection methods.

The history and development of aerial archaeology has been comprehensively documented from the European perspective by Crawford (1954), Deuel (1969), Wilson (1982) and Riley (1987), and for North America by Lyons and Avery (1977) and Ebert (1984, 1988). Detailed descriptions of the methods and equipment used in aerial archaeology are found in Riley (1987) and Ebert (1984, 1988) and in Scollar et al (1990). The use of satellite remote sensing data for archaeological prospection can be seen as a direct development from aerial archaeology. Previous archaeological applications of satellite remote sensing data are now reviewed.

#### 6.4 Archaeological applications of satellite remote sensing

Early archaeological applications of satellite remote sensing date to the late 1970s, when archaeologists working in North America began to experiment with data generated by the NASA Earth Resources Technology Satellite (ERTS) program. ERTS 1 (later to be renamed Landsat 1) was launched on July 23 1972 and the first publicised archaeological application of the data from its Multispectral Scanner (MSS) sensor was the identification of the Egyptian pyramids from MSS imagery (Quann and Bevan 1977).

The identification of the shadow cast by the Great Pyramid at Giza through the visual inspection of data gathered by a sensor operating at over 900 km above the Earth

effectively demonstrated the potential for archaeological applications. However, key limitations inherent in the use of satellite remote sensing products were also identified in this early study (Quann and Bevan 1977, Hamlin 1977, Farley et al 1990).

In 1978, archaeologists from the U.S. National Parks Services Remote Sensing Division, based in New Mexico, undertook a larger project involving MSS data. Exploration plans for the National Petroleum Reserve on the Alaskan North Slope required the archaeological survey of an immense area measuring approximately 92,000 hectares. Conventional ground survey methods were considered impractical because of the size and general inaccessibility of the project area. Much of the terrain was could only be reached on foot at times of the year when the ground was frozen (Ebert 1978).

Landsat MSS data of the North Slope Reserve was combined with colour infrared aerial photography to develop a classification scheme that reflected the probable density of archaeological remains. Classification from aerial photography alone was rejected as impractical because tens of thousands of photographic frames would be needed and the cost of acquiring, interpreting and control referencing such a large quantity of material was prohibitive (Ebert 1988: 449). Visual interpretation of false colour hardcopy plots produced from the MSS data was carried out to create zonation maps. Coverage of the reserve required the use of 10 full MSS scenes, each measuring 185 km x 185 km. The accuracy of the land zone classification was checked by visual interpretation of small-scale colour infrared aerial photography for sample areas and by confirmation of selected zone boundaries in the field by helicopter borne survey teams (Ebert 1988).

By the mid 1980s, the digital processing of satellite sensor data, including the multispectral classification and image enhancement methods, were being used to supplement visual interpretation in archaeological applications. Dorsett et al (1984) carried out a visual classification of Landsat MSS data in an attempt to identify



locations likely to contain archaeological remains in an area of Libya. Ground checking of the MSS derived land cover classification revealed that visual interpretation of the MSS imagery had failed to identify significant local variations in ground cover conditions in some valley floor situations. The limited spectral and spatial resolution of the MSS sensor was considered as an important factor in the inability to discriminate between ground cover classes in this environment (Dorsett et al 1984). The supervised classification of Landsat MSS data was used to produce stratified land cover maps for archaeological predictive modelling in advance of a major construction project on the Delaware coastal plain (Custer et al 1986). In this project, image-training areas were checked on the ground and multispectral classification methods were used to create a map of 'site likely' areas along the proposed highway route.

Madry and Cumley (1990) describe an archaeological survey of the Arroux river valley of the Burgundy region of France using satellite remote sensing, scanned aerial photography and GIS. Classification of Landsat MSS data was used to produce a land cover and land use map and to provide background information for the project. Attempts to locate known Gallo-Roman villa structures from the MSS data were however unsuccessful. The coarse spectral resolution and spatial resolution of MSS were identified as the main obstacles to progress in the direct detection of villa sites and other archaeological features (Madry and Crumley 1990: 369).

The integrated use of Landsat Thematic Mapper (TM) and aerial photography to record and classify wetland areas in Cumbria, is reported by Cox (1992). The aim of this project was to establish whether archaeologically important peats and wetlands could be identified and mapped through the digital enhancement of TM data. Remote sensing personnel at the UK National Remote Sensing Centre carried out the digital processing of the TM data. Aerial photographs were then used to assess the performance of the classified TM data in identifying peat and wetland land cover types (Cox 1992: 249).

Experimentation with the TM data showed that image classification using the first principal component of selected spectral bands (PC1), in combination with the band 4/ PC1 ratio and raw band 5 data, were more effective than classifications based on the raw TM band combinations (Cox 1992: 259-260). By comparison with conventional aerial photography, TM data was found to offer significant advantages in terms of its spectral range and sensitivity and its lower cost where large areas were investigated. Small, waterlogged areas of sub-pixel size could be identified from the TM data in this environment because of the high spectral contrast between these features and background land covers. While the satellite data had coarse spatial resolution when compared to conventional aerial photography, Cox comments that it could profitably be used alongside aerial photography to overcome some limitations encountered when using aerial photography alone (Cox 1992: 260).

Showalter (1993) investigated the potential application of Landsat TM data to map prehistoric Hohokam irrigation canal systems, in the semi-arid environment of the Salt river basin near Phoenix, Arizona. Showalter demonstrated that Landsat TM data could be used to supplement the conventional aerial photographic methods traditionally used to map prehistoric canals in this landscape. Unlike Cox, Showalter found that no discernible advantage was gained from spectral enhancement prior to multispectral classification (Showalter 1993: 85). Spatial enhancement methods, specifically the application of convolution filters designed to emphasise linear features, increased the visibility of known canal features and indicated the presence of additional unrecorded extensions to the known canals network in some areas (Showalter 1993: 88). A full assessment of the potential of Landsat TM was not made because the data available for use in the project did not include TM band 5 coverage of the study area (Showalter 1993).

Wilkinson (1990) was able to trace ancient 'hollow way' routes connecting large tell mounds in the North Jazira of Iraq from a visual interpretation of Landsat TM imagery and incorporated this information into a regional construction of settlement and communication patterns (Wilkinson 1990: 52, fig. 2). Complex wadi networks

extending over tens of kilometres were also readily identified from the TM data, providing information on the distribution of groundwater resources that may have influenced the palaeoeconomy of the study region (Wilkinson 1990: 51).

Satellite borne multispectral digital scanner data and high resolution photographic products have been integrated by archaeological workers in recent survey applications. Cleuziou et al (1992) made use of Landsat TM data alongside declassified satellite photography from the Soviet Soyuz Kate 200 program and conventional aerial photography and ground survey to examine the palaeohydrology of a large region in the Yemen. In a separate project, Brackman et al (1995) used a combination of Landsat TM and KFA-1000 high-resolution satellite photography to investigate ground water resources and reconstruct water supplies for the Roman city of Persius in central Anatolia.

The Persius project illustrates the potential for integrated analyses using multi-sensor earth observation data, Global Positioning Systems (GPS) and geographic information systems (GIS) technology. Brackman et al used declassified KFA-1000 photography to overcome local difficulties in gaining access to mapping at scales suitable for archaeological fieldwork. KFA-1000 imagery was referenced to ground features in the field using a hand held Global Positioning Satellite (GPS) receiver to provide a level of spatial control adequate for the subsequent GIS based modelling (Brackman et al 1995: 24). An initial multispectral classification of the TM data identified geological formations which were likely to act as aquifers. These formations were treated as the supply points for a postulated aquaduct network to supply the Roman city. The course of a possible water supply network was then projected using adapted hydrological modelling tools. Subsequent field investigations along the reconstructed network route found previously unrecorded sections of Roman aquaduct (Brackman et al 1995: 3).

Spaceborne radars are described in detail by Elachi (1987) and the development of the American space shuttle SIR-C and X-SAR program is reviewed by Evans et al

(1997). High resolution SIR-C/X-SAR radar imagery has been merged with visible and near visible region multispectral data in some non-archaeological applications (e.g. Haak and Sloneker 1994, Welch 1984). The penetrating capabilities of spaceborne radar have proven useful for specific archaeological applications. Archaeological applications of radar imagery include the location of structures concealed beneath dense vegetation canopies (Adams et al 1981) and the mapping of palaeohydrological features beneath modern arid land surfaces (Cleuziou et al 1992, McCauley et al 1986, McCauley et al 1982, Pachur and Rottinger 1997, Schaber et al 1986).

## 6.5 Summary of archaeological applications

Early archaeological applications of satellite remote sensing products date from the late 1970s and initially emphasised the visual interpretation of raw data and manual tracing from hardcopy output onto transparent overlay materials using methods similar to those used in aerial photo-interpretation (Ebert 1984: 344). Multispectral scanner (MSS) data from the Landsat program was the first satellite remote sensing product available to archaeologists and applications using MSS data dominate the archaeological satellite remote sensing literature up until the late 1980s.

In regional scale archaeological survey applications, satellite remote sensing products have been used to gain an overview of large areas, particularly in regions where aerial photographic coverage or suitable conventional mapping are either unavailable, or are otherwise impractical for the planned project (Ebert 1984, Brackman et al 1995). Remote sensed data may supply archaeological and palaeoenvironmental information not available from topographic maps (Wilkinson 1990, Cox 1992, Showalter 1993, Brackman et al 1995).

The archaeological applications found for satellite remote sensing products have become increasingly sophisticated. By the late 1980s, multispectral classification methods and interactive processing of sensor data using digital image processing has

generally replaced visual interpretation for archaeological applications (e.g. Custer et al 1986, Madry and Crumley 1990, Showalter 1993). The manipulation or pre-processing of raw sensor data prior to classification has also been found to be effective in some archaeological remote sensing projects (Cox 1992). The availability of Earth observation products suitable for archaeological applications was expanded dramatically with the launch of the TM sensors on Landsats 4 and 5 in 1982 and 1984 and with data from the SPOT HRV and Panchromatic sensors after 1986. More recently, medium and high resolution declassified satellite photographic products, such as CORONA, Kate 200 and KFA/KVR-1000, have been used alongside Landsat TM and SPOT data in archaeological remote sensing applications (Brackman et al 1995).

## 6.6 Sensors and data selection

The remote sensing component of the project took place against a background of rapid and continuing developments in the distribution and availability of Earth observation products. Significant developments include the distribution, in late 1995, of the first low cost archived Landsat TM data under the terms of commercial licensing agreement between the US Government and the Earth Observation Satellite Company (EOSAT). Subsequently, archived TM data have been distributed at data cost by the United States Geological Survey (USGS) with metadata made available as part of the EROS Data Center (EDC) Global Land Inventory System (GLIS).

Intelligence satellite products of potential use to archaeologists have been declassified by the United States and Russian governments in recent years. Some imagery from medium and high-resolution Russian photographic satellites has been available since the early 1990s, beginning with the relatively low resolution KATE 200 photography (e.g. Cleuziou et al 1992) and culminating in the release of < 5 metre resolution KVR 1000 data (Brackman et al 1995, Mussio and Light 1995). Similarly, extensive satellite photography from the United States' CORONA, ARGON and LANYARD programs was declassified and made available to the wider

remote sensing community in 1995 (McDonald 1995a, McDonald 1995b, McDonald 1997).

Multispectral data were used in the present project to investigate the appearance of archaeological mounds in different regions of the spectrum. The two multispectral data types considered for the project were Landsat TM and SPOT High Resolution Visible (HRV). The relatively large size of archaeological mound sites, and similar spatial resolution of the SPOT and Landsat TM data (IFOV 28.5m - 20m) make differences in spatial resolution between the two sensors relatively unimportant in comparison to the spectral range of the data.

Landsat TM data was chosen in preference to SPOT HRV because it includes data bands in the mid infrared and thermal infrared regions of the spectrum. The archaeological applications of TM data have been relatively little studied in comparison to those of Landsat Multispectral Scanner (MSS), largely because of the cost of acquiring TM imagery (Landgrebe 1997, Ebert 1988). The availability of low cost archived TM imagery, together with developments in software tools and desktop computing platforms has made multispectral remote sensing increasingly accessible as a practical tool for archaeological survey projects. The potential archaeological survey applications of TM data are therefore likely to be of interest to increasing numbers of archaeologists.

Satellite remote sensing data have occasionally been specially contracted for archaeological applications where a programme of detailed ground observation is planned to coincide with image acquisition (e.g. Madry and Crumley 1984), but archival data were used for the present project. The use of the most recently acquired data was considered to be less important for archaeological site location than in traditional land use classification applications. The use of recent imagery is necessary in most land use classification studies because patterns of land use are subject to change over time and information about current land use patterns is usually sought. In contrast to the land classification case, the archaeologist wishes to identify a finite



set of locations that are fixed in space. The age of the data is less important in archaeological applications than obtaining the best possible visibility conditions. The use of previously collected or 'archival' data allowed a wide choice of high image quality scenes and reduced data acquisition costs.

Multidate remote sensing data, i.e. coverage of the same area obtained at different dates, allows the study of changes in the spectral characteristics of target features or larger areas over time. Time dependent variations in the visibility of archaeological features have not been considered in most archaeological studies, but a multidate perspective is found to be useful in many non-archaeological applications. As an example, Pax-Lenney and Woodcock (1997) report the use multidate imagery to classify land use for an intensively cultivated, semi-arid area of Egypt. Of the nine Landsat TM scenes used in classification, all were found to contribute significantly to the classification process. However, a single key scene was identified as the major source of information for the final land use classification. These findings indicate both the potential value of multidate coverage and the significance of data selection where a single remote sensing scene is to be used for land use classification purposes.

An additional advantage in the use of multidate imagery is that it extends the range of possible classification methods to include change detection techniques (e.g. Richards 1993). Change detection is commonly used to study the dynamics of agricultural croplands and natural vegetation covers but is also in specialist applications such as monitoring lake level or shoreline change and in the assessment of the damage caused by forest fires. In the context of archaeological prospection, it was hoped that change detection techniques might highlight time dependent changes in vegetation covers that could be used to discriminate between archaeological mounds and their backgrounds. Change detection has the advantage that it can be performed using simple techniques, such as the image subtraction of single data bands or multi-band combinations. Alternatively, spectral indices such as the Normalised Difference Vegetation Index (NDVI), or image transforms such as Tasselled Cap or principal component transformations can be used to emphasise

particular types of information (e.g. Kauth and Thomas 1976, Crisp and Kauth 1986, Jensen 1986). Indices and transforms offer additional benefits in terms of data compression and in the standardisation of the spectral variation caused by different atmospheric and illumination conditions.

The interval chosen for analysis was mid through late summer, i.e. late June through early September. This period was chosen partly because archaeological fieldwork was planned for these dates and this timing would allow ground observation to be carried out alongside this work. It was also anticipated that changes in soil moisture conditions between mid and late summer might produce changes in the appearance of the agricultural and semi-natural vegetation covers at archaeological mound sites. Although Landsat TM data could have been chosen from different years to span the chosen study period, two scenes from the same year were selected in order to eliminate some potential sources of spectral variation and to simplify interpretation.

High radiometric quality data were desirable to allow the spectral characteristics of past settlement sites and the potential for archaeological prospection applications to be fully explored. An obvious data quality requirement was that the data should be free of cloud or atmospheric haze that could obscure parts of the study area or otherwise affect the analysis of archaeological site spectral characteristics. Metadata on the radiometric quality and cloud cover conditions of prospective Landsat TM scenes was checked using the USGS GLIS database and high quality scenes with minimal cloud cover previewed using the GLIS image browser facility.

In addition to the multispectral data, it was desirable to investigate the potential use of higher resolution satellite remote sensing products. A single SPOT Panchromatic scene for the study area was made available for analysis by arrangement with Dr Orrin Shane of the University of Minnesota Science Museum. The SPOT data was originally acquired to capture the appearance of the study area under light snow cover conditions to test whether subtle topographic features would be revealed, as can sometimes occur in aerial photography (Shane pers. comm.). In the context of the

present project, the main value of the SPOT Pan data was anticipated to be as a means to establish geographic control in the absence of mapping coverage at scales adequate for archaeological fieldwork. It was also hoped that the presence of extensive areas of bare soil in the SPOT scene might enable archaeological features to be identified in irrigated crop fields.

The remote sensing data selected for use in the project were two Landsat Thematic Mapper 5 scenes at World Reference System (WRS) coordinates path 177 row 034, acquired on 23 June 1984 and 11 September 1984. The 185 km x 185 km Landsat TM scenes extended beyond the study area to include areas of surrounding terrain to the south, west and north. The SPOT 1 Panchromatic data used in the project consisted of a single 60 km x 60 km nadir mode scene, acquired on 9 December 1989 and giving coverage of the Çarsamba fan study area.

## 6.7 Characteristics of the remote sensing data used

Townshend (1980) identifies four components of the spatial resolution of imaging systems. These are; the geometrical properties of the system, the ability to distinguish between point targets, the ability to measure the periodicity of repetitive targets, and the ability to measure the spectral properties of small targets (Townshend 1980). From previous archaeological surveys, that the area of individual settlement sites within the Çarsamba fan study region is known to vary from less than one hectare in extent to more than 40 hectares. The nominal 28.5 metre instantaneous field of view (IFOV) of the Landsat TM sensor should be capable of locating features throughout this size range and might even be usefully resampled to a larger pixel size in the case of medium and large sites (Fuller et al 1989, Atkinson and Curran 1997). The 10 metre IFOV of the SPOT Panchromatic sensor should allow features of rather less than 1 hectare in extent to be identified. The nominal geometrical properties of both Landsat TM and SPOT Panchromatic data imply a level of spatial resolution that is more than adequate for the detection of archaeological mounds.

The second and third criteria identified by Townshend assess sensor performance against specific reference standards and are less significant in terms of detecting unrecorded archaeological mounds than the fourth, the ability to measure the spectral properties of small targets. The effective spatial resolution of remote sensing data will be influenced by the level of spectral contrast between the target feature and its background. The level of contrast between a target object and its background can be expressed as the ratio of the spectral modulation measured across the whole image against that of the target object (Mather 1987: 39-40). The spectral properties of archaeological mounds and their background environments are discussed in the section on prospection methodology.

The spatial resolution of the SPOT Pan and Landsat TM data are compared in Figure 6.1, which shows unresampled SPOT Pan and Landsat TM (band 2) data for a matched 3km x 3km area to the west of Çumra. Landsat TM band 2 data is used to facilitate comparison because it is acquired in a similar spectral range to that used by the SPOT Panchromatic channel. The contrast in spatial resolution between the SPOT and Landsat data is apparent from the pixellated appearance of the Landsat image in Figure 6.1 b. Linear features such as roads, canals and field boundaries appear more clearly defined on the SPOT data and shadows are visible beside rows of trees grown as windbreaks at field boundaries in the lower right of the same image. Figure 6.1 also shows the archaeological mounds of Sircali Hüyük and Çumra Mezarlik Hüyük

In terms of the spectral domain, Landsat TM data contains seven bands, allowing the spectral characteristics of archaeological sites to be examined at visible blue/green through thermal infrared wavelengths (0.45  $\mu\text{m}$  - 12.5  $\mu\text{m}$ ). SPOT Panchromatic data is acquired within a single broad data band in the wavelength range 0.51-0.73  $\mu\text{m}$ , approximately equivalent to the range of TM data bands 2 and 3. The radiometric resolution of the data recorded by both sensors is 8-bit, with individual pixels in each data band having a possible range of values between 0 and 255.



Scale 1: 40 000  
10 0 Kilometer



Figure 6.1 Satellite image subsets for the area west of Cumra. Top: SPOT Panchromatic, Lower: Landsat Thematic Mapper (TM) band 2 data.

The position of the data bands of the SPOT Panchromatic and Landsat TM sensors are shown along with generalised reflectance profiles for water, soil and vegetation in Figure 6.2. The position of the Landsat TM thermal band (10.4  $\mu\text{m}$  - 12.5  $\mu\text{m}$ ) is not shown in figure 6.2 and is discussed in a separately below. The wavelength ranges of the Landsat TM bands are designed to record information for use in a wide variety of applications. Some key applications identified for the individual TM data bands are summarised in Table 6.1.

TM Band	Spectral Region	Application
1	Blue .45-.52 $\mu\text{m}$	Mapping coastal water areas, distinguish between soil and vegetation, forest type mapping, detecting cultural features
2	Green .52-.60 $\mu\text{m}$	Corresponds to green reflectance of healthy plants, cultural feature identification
3	Red .63-.69 $\mu\text{m}$	Differentiate between plant species, soil boundary and geological boundary delineation, identify cultural features
4	Reflective IR .76-.90 $\mu\text{m}$	Responsive to vegetation biomass, crop identification and emphasises soil/crop, land/water contrast
5	Mid IR 1.55-1.74 $\mu\text{m}$	Sensitive to amount of water in plants, crop drought studies, plant health analysis. Discriminate between cloud, snow, ice
6	Thermal IR 10.4-12.5 $\mu\text{m}$	Vegetation/crop stress detection, heat intensity, insecticide applications, thermal pollution, detect geothermal activity
7	Mid IR 2.08-2.35 $\mu\text{m}$	Discriminate rock types, soil boundaries, vegetation moisture content

Table 6.1 Landsat TM data band features and common applications. (after *ERDAS Imagine Field Guide 1994: 68*).

Landsat TM thermal infrared image data is acquired with a 120 metre IFOV and resampled before distribution to match the 28.5 metre IFOV of the other TM data bands (Mika 1997). The coarser spatial resolution of TM thermal band data relative



to the visible and near visible bands restricts the range of applications for which it can be used. This factor, and the difficulty of interpreting thermal features, have led to TM band 6 data being used in fewer applications than the TM visible and reflective infrared data (Campbell 1996: 264).

Price (1981) investigated potential applications of the thermal channel added to the MSS sensor carried by Landsat 3. The Landsat 3 MSS thermal data (MSS band 5) was acquired with an IFOV of 127 metres as opposed to the Landsat TM band 6 data IFOV of 120 metres. The relatively small difference in the IFOV of the MSS and TM thermal data is less important than the differences in its radiometric resolution. The radiometric resolution of MSS data is also lower than that obtained by the TM sensor, with a possible range of values between 0 and 127 (Lillesand and Kiefer 1987).

The spectral range of the MSS and TM thermal data are nearly identical and are designed to record energy in the emitted thermal infrared region of the spectrum (MSS band 5: 10.4 - 12.6  $\mu\text{m}$ , TM band 6: 10.4 - 12.5  $\mu\text{m}$ ). Price suggests that while the Landsat 3 thermal band data contains information not recorded by the other MSS channels, it should be omitted from routine land cover analyses because of the complexity of interactions between topographic, land cover and atmospheric effects (Price 1981). Similarly, Toll (1985) found that TM thermal band 6 data did not contribute significantly to the accuracy of land cover analysis carried out for test areas in the northern United States.

The presence of moisture is an important factor in thermal remote sensing as it can greatly alter the thermal properties of soils and rocks (Campbell 1996: 256). For this reason, thermal data is of value in monitoring moisture levels. Vegetation also affects the thermal properties of land surfaces. Daytime thermal remote sensing can also be affected by the differential solar heating and shadowing of land surfaces according to the topography of the imaged area. The combination of these factors and the variable

characteristics of different land surfaces can result in complex patterning in thermal images (Campbell 1996).

The thermal landscape different to the reflected landscape and thermal features are often difficult to interpret intuitively. The timing of the overpass of the Landsat MSS and TM sensors is also too early to exploit maximum thermal contrast conditions, which occur in early afternoon (Price 1981). The registration of TM thermal band imagery to ground features is hindered by its coarse spatial resolution and the difficulty of identifying ground features (Campbell 1996). This difficulty in registration is addressed by resampling of the Landsat TM thermal data to match the pixel size of the visible and near visible infrared data bands before the data are distributed (Mika 1997). This resampling of thermal band data results in the calculation of brightness values other than those originally recorded.

## 6.8 The geocoding of satellite data

The data recorded by satellite borne sensors tends to have highly stable internal geometry making it ideal for mapping applications (Chavez 1984). Suggested minimum scales for map products produced from the sensors used in the present project are 1:100,000 for Landsat TM and 1:25,000 for SPOT Panchromatic channel data (Chavez 1986, Colvocoresses 1986). Landsat and SPOT data are gathered along a ground track that is aligned to the orbital path of their respective satellite platforms and not along north-south axes. In order to generate maps from the satellite data for use alongside conventional topographic maps it is first necessary to rectify the satellite image data, i.e. project it onto a plane conforming to map coverage of the study area, so that map coordinates could be assigned.

The smaller pixel size of the SPOT Pan data gave greater precision in the identification of Ground Control Point locations (GCPs) than the Landsat TM data. In addition, more potential ground control points could be located on the SPOT Pan imagery because of the higher level of spatial detail it contains.

A two-step procedure was used to rectify the project imagery. In the first stage, the SPOT Pan scene was rectified to the 1:25,000 topographic map coverage using ground control point locations with known map coordinates. The Landsat TM image data were then registered to the rectified SPOT Pan data in the second stage of the procedure. By these means the three remote sensing scenes were brought into registration and rectified to a common coordinate system as used on the topographic map coverage of the study area

The potential population of GCPs available for rectification was limited by the visibility of potential control point locations on the SPOT Pan imagery. The preferred sequence of operations for collecting potential ground control point locations was therefore to identify potential control points on the imagery in the first instance and then to obtain map coordinates for these points. A network of 89 GCP locations was selected from the imagery across an area extending approximately 25 kilometres by 30 kilometres and enclosing the study area. Ground coordinates for each GCP were digitised from tracings made onto drafting film media from 1:25,000 scale topographic maps.

A large population of GCPs was used to ensure a robust transformation of the image data and to ensure the averaging of the positional error introduced by the need to work from map tracings. A first-order polynomial transformation was used to obtain a linear transformation of the image data. Eight GCPs from the original 89 were eliminated in the course of refining the transformation. A root mean squared error (rmse) of 1.71 pixels in the x-axis and 1.91 pixels in the y-axis, or total combined rmse in both axes of 2.56 pixels, was obtained in the final transformation of the SPOT Pan data using the remaining 81 control points. It was considered more important to retain a robust network of GCPs distributed over a wide area and offering good rectification geometry, than to seek reductions in the rmse through the elimination of further GCPs .

The error vectors of retained GCPs were variable in direction and magnitude suggesting the absence of a systematic error component. Individual GCPs were capable of relocation on the SPOT Pan data to within 0.5 pixels in either axis. Digitised map coordinates for the individual GCPs were capable relocation within a precision of 0.35mm or less on the original map tracings.

The accuracy of the transformed SPOT Pan and Landsat TM data was regarded as adequate for its intended usage to locate features of potential archaeological interest in the field and to enable the production of image derived spatial coverages which could be used alongside conventional maps. Rectification degrades the spectral quality of remote sensing data because of the interpolation and resampling operations that are involved. For this reason, multispectral classification and other spectral analyses described in the sections on archaeological site location were carried out using the un-resampled data. Where rectification was required it was carried out after other processing was completed.

## Chapter 7: Remote Sensing on the Çarsamba Fan.

### 7.1 Introduction.

The task of locating archaeological sites from remote sensing data can be approached using both synoptic (e.g. landscape classification or stratification) and specific or direct detection methods. Synoptic approaches seek to partition the landscape with the aim of isolating areas likely to contain archaeological sites and have frequently been tried by archaeologists attempting to locate archaeological sites from remote sensing data (e.g. Custer et al 1985, Ebert 1988, Cox 1992). In this chapter the potential of the second approach, the direct detection of archaeological settlements through recognition of their specific reflectance characteristics is examined. The reflectance characteristics of archaeological settlements on Landsat TM and SPOT Panchromatic mode data are investigated and factors affecting the visibility of past settlements are discussed. Field experiments in the detection of archaeological settlements using multirate remote sensing data are also described.

### 7.2 The spectral characteristics of archaeological settlements.

The initial visual inspection of Landsat TM imagery for the Çarsamba fan study area showed some archaeological mounds to be readily visible, whilst others could not be distinguished from the surrounding landscape. The investigation of the origins of this observed variation in the appearance of archaeological mounds was identified early in the project as an important area of inquiry with regard to gaining an understanding of factors affecting the visibility of archaeological mounds on Landsat imagery.

The distribution of reflectance values recorded for a sample group of thirty-five archaeological sites is shown in figure 7.1. It is apparent from these data that the reflectance spectra of archaeological mound sites are not confined within narrow brightness (DN value) ranges. The range of reflectance values recorded over archaeological mounds is particularly broad in bands 1, 5 and 7, covering around 40% of the range of the TM sensor. Data values in band 1 are skewed towards the

lower range, while the data for TM bands 2 and 3 show secondary peaks at higher DN values. The highly variable reflectance characteristics of archaeological mounds indicate that the classification of all archaeological mounds to a single spectral class is not a sensible objective.

The surface of archaeological mounds consists largely of weathered mudbrick material with some form of vegetation cover. While variation is observed in the composition of mudbrick at archaeological sites (e.g. Davidson 1973, Davidson 1976, Rosen 1986, Matthews et al 1997), variations in the quantity and distribution of vegetation appear to be more significant in terms of the appearance of archaeological mounds on satellite imagery. The weathered mudbrick of archaeological mounds is highly reflective, as can be seen from the appearance of the eroding slopes and upper areas at larger mounds, which are sparsely vegetated. The lower reflectance of the vegetation cover growing on mounds contrasts strongly with the high reflectance of bare slope areas. In this respect the classification of archaeological mounds raises similar issues to those encountered in the spectral classification of semi-arid rangeland covers (Graetz and Gentle 1982, Huete and Jackson 1987, Knick et al 1997).

The influence of vegetation cover on the appearance of archaeological mounds on satellite data can be observed in situations where mounds are enclosed by a boundary wall or fence. Unfenced settlement mounds on the Çarsamba fan are generally sparsely vegetated with extensive areas of bare soil surface. The open vegetation cover characteristic of such mounds appears to be maintained by grazing pressure. Where grazing is reduced or eliminated by the presence of an enclosing wall or fence, a dense vegetation cover typically develops. A similar process is observed in experimental fenced erosion control areas to the north of the study area near Karapınar, suggesting that the Konya basin would revert to steppe grassland in the absence of agriculture and grazing animals (Roberts 1981). The limits of enclosed mounds tend to be clearly defined on satellite imagery by the contrast between the vegetation cover and land use on either side of a boundary wall or fence.



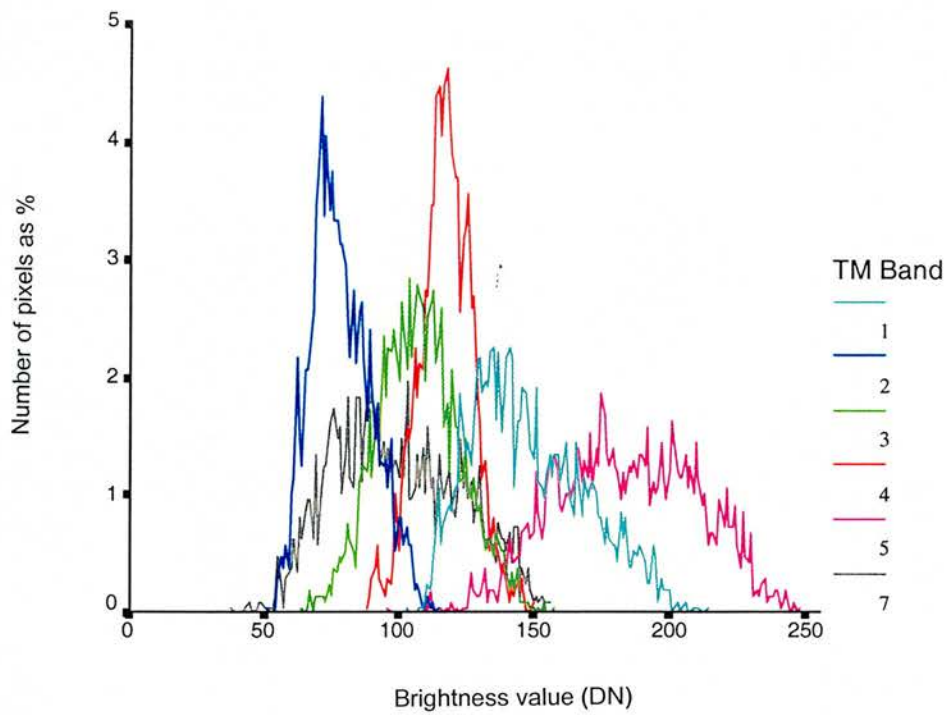


Figure 7.1 Merged brightness values in different Landsat TM bands for thirty-five archaeological mounds.

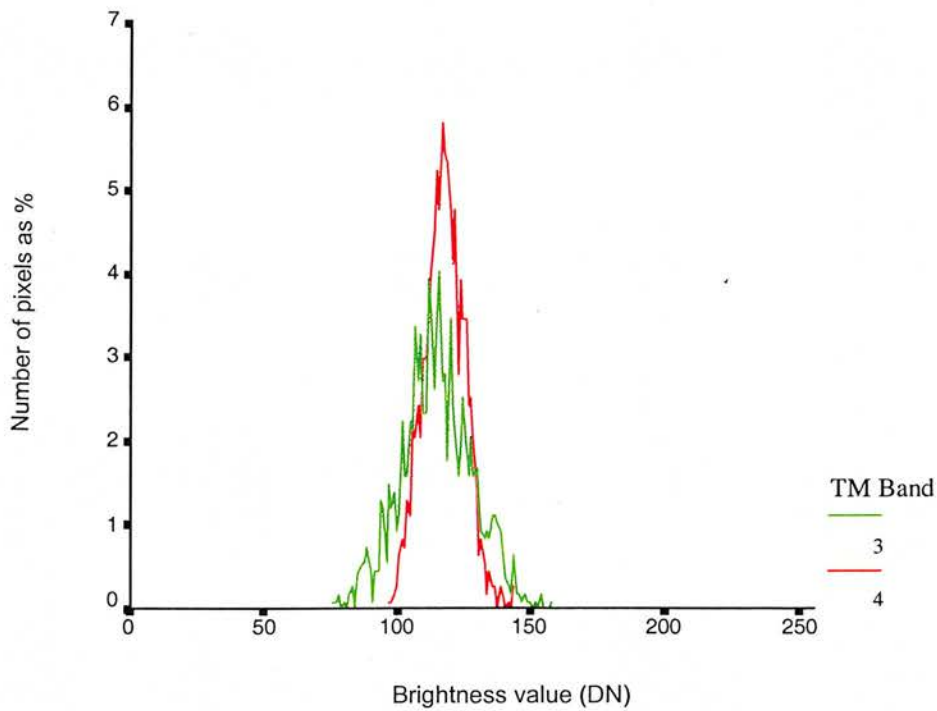


Figure 7.2 Brightness values in Landsat TM bands 3 and 4 at open uncultivated mounds (merged data).

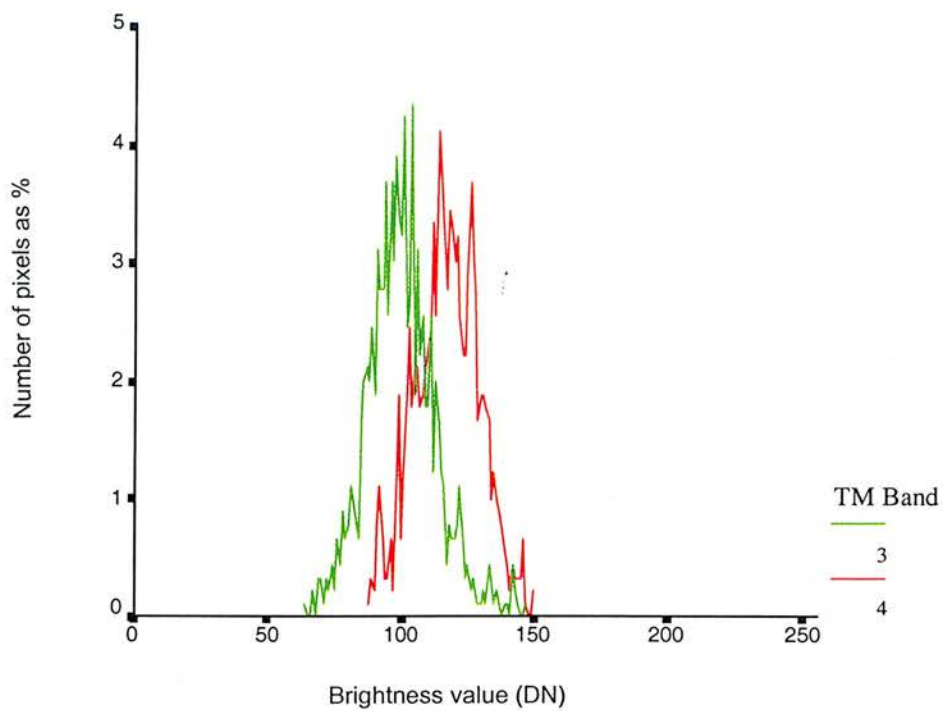


Figure 7.3 Brightness values in Landsat TM bands 3 and 4 at enclosed mounds (merged data).

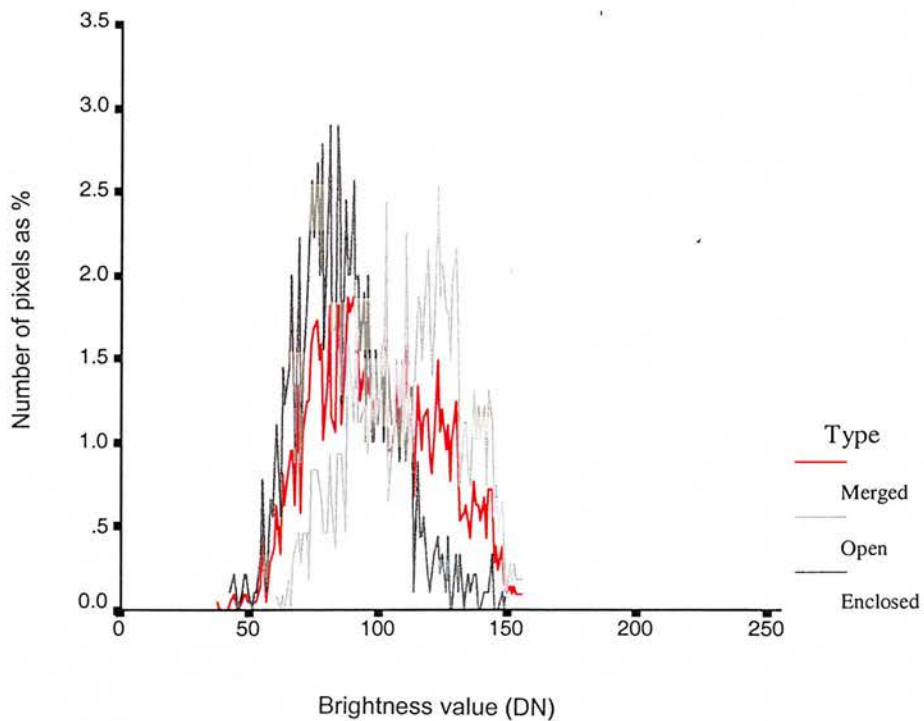


Figure 7.4 Merged Landsat TM band 5 values for all open and enclosed mounds. Note merged values obscure offset peak brightness values of the two types of mound.

The most common form of enclosure occurs where mounds near to villages are used as burial grounds surrounded by a gated wall. The two mounds at Çatalhöyük illustrate the different appearance of open and enclosed mounds. Çatalhöyük West has an open type cover, while Çatalhöyük East has developed a more dense vegetation cover within the perimeter fence surrounding the mound.

A simple type classification is proposed to describe the gross variation observed in the surface conditions at archaeological mounds. Mounds may be classified into open uncultivated, enclosed and cultivated categories according to their surface cover and land use characteristics. These three categories of mound exhibit distinct spectral characteristics and require different approaches to classification and detection. Differences in the reflectance characteristics of the three categories of mound are now described.

Most archaeological mounds within the study area are of the open uncultivated type. The reflectance characteristics of open uncultivated archaeological sites are easily distinguished from those of agricultural land covers and more closely resemble those found in urban settings. Open uncultivated mounds typically appear as bright features on the Landsat and SPOT data because their reflectance characteristics are dominated by a bare soil component. Examples of open mounds include; Türkmenkarahöyük, Seyithan Hüyük, Domuzbogazliyan Hüyük, Kerhane Hüyük, Çatalhöyük West, Kizlar Hüyük, Tekke Hüyük and Karaca Hüyük I. These mounds can often be identified visually on both the Landsat and SPOT data from their characteristic shape and brightness.

The land cover at open mounds displays little seasonal change in reflectance between the June and September Landsat images. This stability contrasts strongly with the changing reflectance characteristics of cultivated fields, but less strongly with areas that are given over to semi-permanent grazing.

The reflectance characteristics of both open and enclosed archaeological settlement mounds are a product of the interaction of vegetation, soil and plant litter

components, with soil reflectance being most significant component at open mounds. The vegetation cover on open sites is typically sparse and dominated by grasses and comprises a limited range of species that tolerate grazing, soil disturbance and aridity. At open tells, parameters such as elevation, gradient, drainage and orientation with respect to sun and prevailing winds interact with patterns of land use, including grazing pressure and soil disturbance, to create a range of surface cover conditions. Rosen has highlighted the importance of these factors in producing variable erosion rates in different areas of the same mound (Rosen 1986).

A common feature observed at open semi-naturally vegetated sites is the presence of a sparsely vegetated summit area, surrounded by more dense growth on the mound slopes, creating a halo or corona effect that is sometimes visible on satellite imagery. The density of vegetation cover also tends to vary between slopes of different aspect, being typically most dense on north-facing slopes and least dense towards the upper areas of mounds and on eroding slopes. Ground observations at large sites such as Turkmenkarahöyük were found to allow the influence of variation in features such as vegetation cover, slope, aspect and shadowing to be assessed in a way that is not possible at smaller sites.

Mounds of the enclosed type tend to be raised tells of medium or large size, i.e. over 5-8 hectares extent. Examples include; Mezarlik Hüyük (Karkin), Mezarlik Hüyük (Çumra), Üçhüyükler Mezarlik I, Çatalhöyük East, Sarlak Hüyük I and II (cemetery mound to west of Sarlak I), Samih Hüyük and Sircali Hüyük. The exclusion of grazing animals appears to be important in allowing a dense vegetation cover to develop at enclosed mound sites. The vegetation cover of enclosed mounds tends to be dominated by grasses, with cultivated trees at some larger mounds, as at Sircali Hüyük, Çumra Mezarlik Hüyük and Karkin Mezarlik Hüyük. There is often disturbance of the mound surface in the form of vehicle tracks or pitting, and buildings or other structures may be present. The vegetation cover at enclosed mounds has a lower near infra red reflectance than is found for growing crop covers, but peak TM band 3 and band 4 values are offset (Figure 7.2).

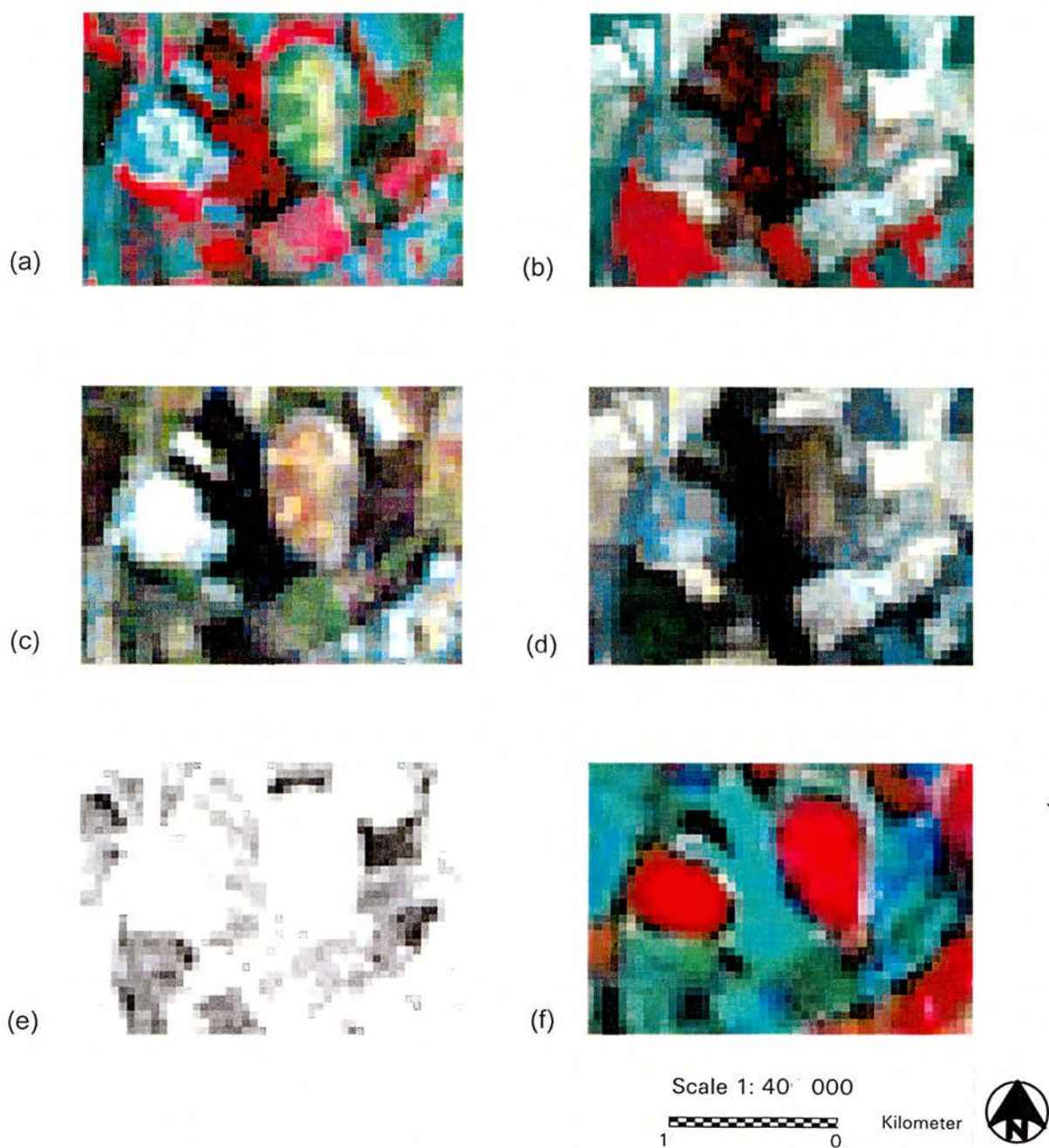


Figure 7.5 Landsat TM views of the mounds at Catalhoyuk. Top: false colour composite view (bands 4,5,3) for June a) and September b). Middle: natural colour composite (bands 3,2,1) of same area for June c) and September d). Lower: e) Change detection view produced by image subtraction of June and September NDVI values, f) Landsat TM thermal and visible data band composite for the Catalhoyuk mounds (bands 6,2,1) showing elevated values over mound surface in thermal band.



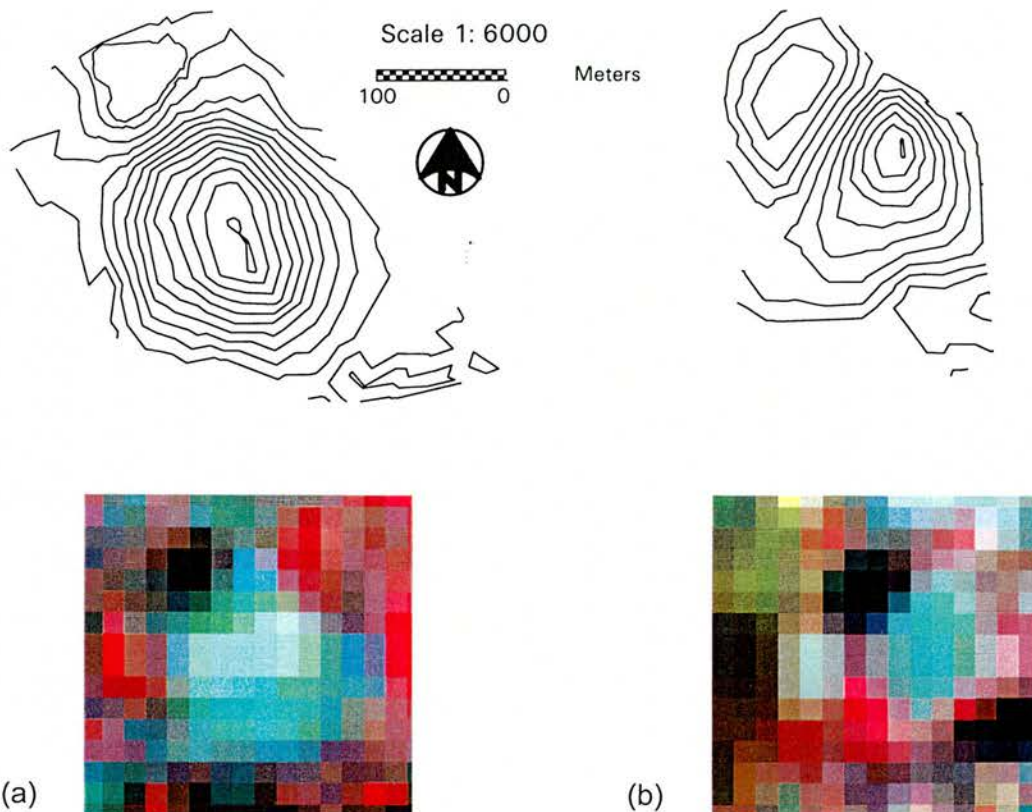
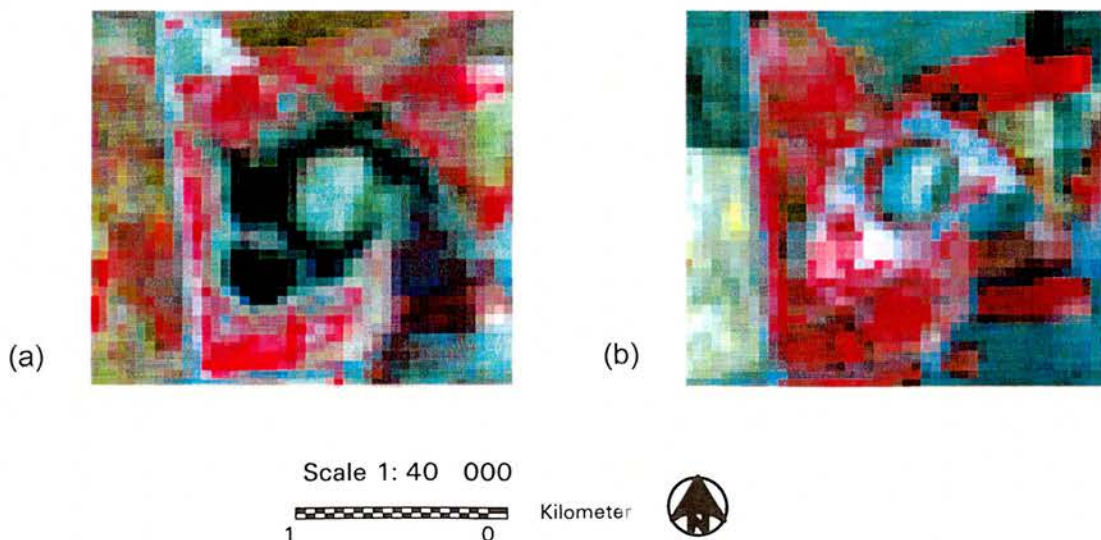


Figure 7.6 Contour surveys of Salur Huyuk (a) and Kervan Huyuk (b), with Landsat TM image chips showing the prominent appearance of the hollow features at both mounds (bands 4,5,3).

Figure 7.7 Arcuate hollow feature at Erminler Huyuk in the eastern fan showing change in appearance on Landsat TM data between June (a) and September (b). The higher reflectance in the September image is produced by bare soil surfaces.





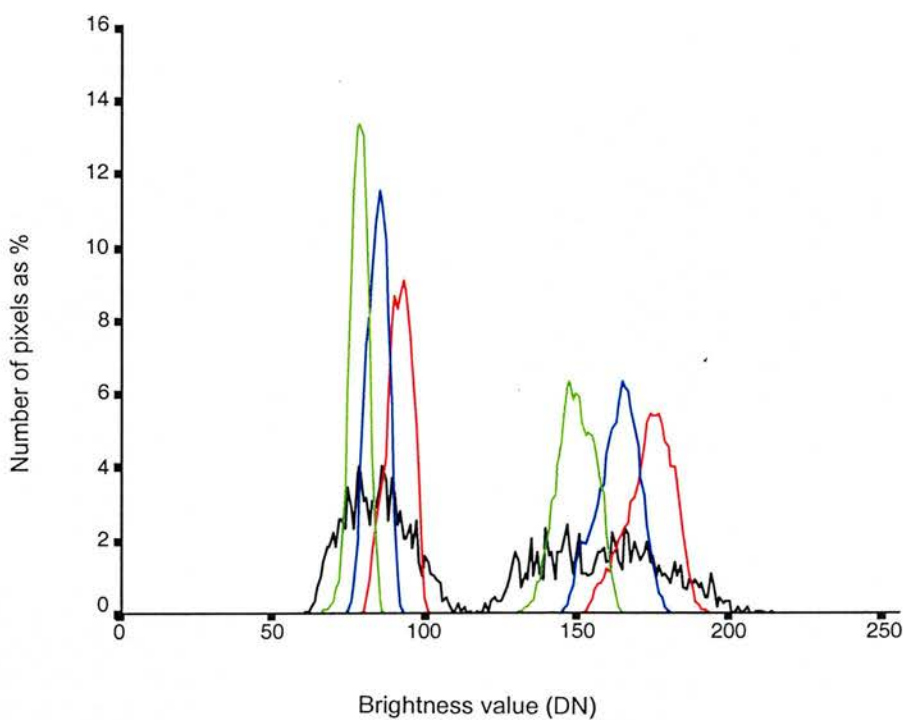
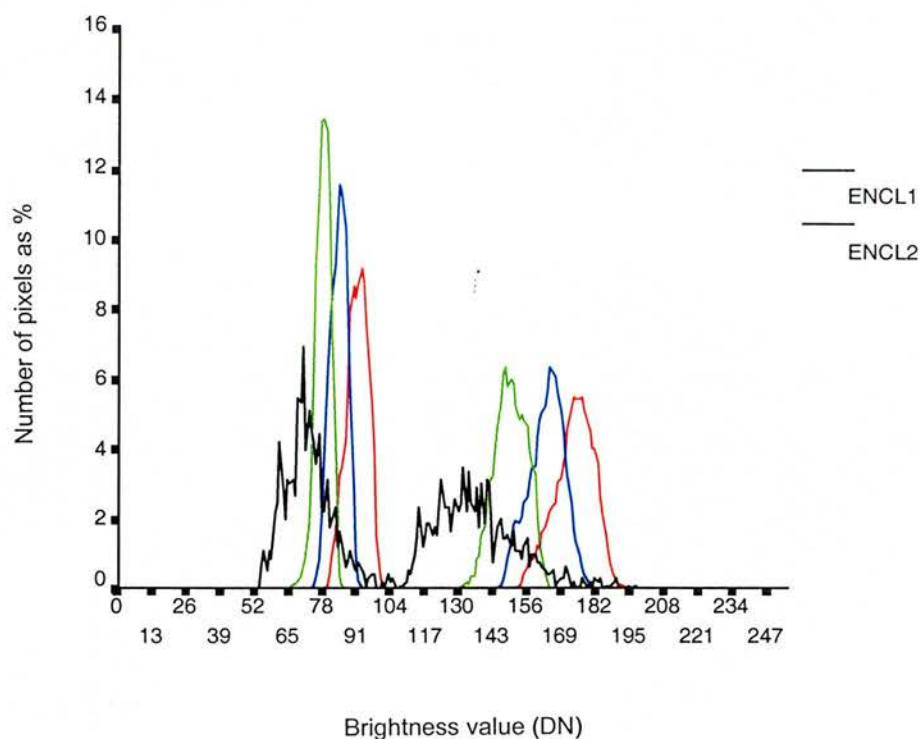


Figure 7.8 Performance of ISODATA classification at enclosed and open mound types. Top: spectral profiles of three mound-associated classes plotted against TM band 1 and 2 values for enclosed mound type. Lower: spectral profiles for the same mound-associated classes plotted against TM band 1 and 2 values at for open mound type. Note partial classification of enclosed type compared to open type.

Enclosed mounds can be difficult to isolate using classification approaches because their vegetated surfaces are spectrally similar to some background vegetation covers. A difference between the reflectance characteristics of enclosed mounds and the surrounding areas is that the vegetation cover at enclosed mounds shows relatively little change over time while the vegetation cover of surrounding crop fields tends to be highly variable. This contrast between the stability of enclosed mound covers and the variable reflectance of cultivated fields can be exploited by choosing remote sensing data for times of year when cultivated fields are cleared of crops, or by the use of multitime imagery in conjunction with change detection algorithms based on vegetation indices or principal component transforms (figure 7.5).

A third type of land cover is found at cultivated sites. Cultivated sites are simply settlement mounds that are brought into crop production. Sites in this group vary from less than one hectare to more than 40 hectares in extent. It is probable that many unrecorded mounds on the Çarsamba fan are located in crop fields and the ability to detect this type of site is likely to be particularly important in increasing knowledge about the settlement history of the fan. Examples of cultivated mounds include; Irmik Hüyük, Salur Hüyük, Halaç Höyüğü, Bostantömek, Tastomek, Kuslu Hüyük, Dolay Höyük, Kervan Hüyük, Beskilise, Efrekoy, Orta Hüyük, Alemdar Hüyük, Kizil Hüyük II, Kizil Hüyük III, Sarlak Hüyük II and Musluk Hüyük. Areas of larger sites are also brought under cultivation, particularly on their more accessible lower slopes, as at Kizil Hüyük I, Kerhane Hüyük and Seyithan Hüyük.

When sites are under growing crops, they cannot usually be distinguished from other crop field areas on the Landsat data. In addition, where cultivated sites are partitioned by field boundaries, their characteristic shape is disrupted, adding to the difficulty of detection. This effect is especially pronounced where different crops are planted in the adjoining fields. Cultivated sites share the highly dynamic surface reflectance characteristics of other areas under intensive agricultural land use. Within the span of just a few months, the surface conditions at a cultivated site can range from bare ploughsoil to a complete vegetation cover of irrigated crops such as beet or cereals. The highest visibility of cultivated sites is obtained after crops are harvested and

before newly planted crops begin to mature, i.e. in the interval between late autumn and early spring.

### 7.3 Mound associated hollows

Shallow depressions or hollows are visible on the Landsat TM imagery adjacent to some archaeological mounds. These hollow features only occur in close proximity to past settlement sites and there is a clear association between the two. Similar features are reported by Wilkinson (1990) in an area populated by tell mound sites in the Jazira of northern Iraq (Wilkinson 1990: 51-53). The hollows visible on the Çarsamba fan can be classified into arcuate and circular types (figures 7.6, 7.7). Arcuate hollows are associated with the settlement mounds at Sarlak Hüyük I, Erminler Hüyük and Pirsanlı (Musalla) Hüyük. Circular hollows are found at Salur Hüyük, Karaca Hüyük I, Cingene Hüyük, Kervan Hüyük, Alanlı Hüyük and Okçu Hüyük II. Locally, the presence of mound associated hollows is not confined to the Çarsamba fan. Similar features are visible from the satellite imagery on the neighbouring May fan, as for example at Alibeyhöyüğü (Alibey Hüyük).

The appearance of both arcuate and circular hollow features changes between the June and September Landsat TM images. In the June image, mound associated hollows appear as areas of low reflectance. The contrast between the low reflectance hollows and the brighter appearance of mound and crop field areas make hollows appear as prominent features in the June image. By September, the reflectance characteristics of mound associated hollows are found to have changed considerably and are less prominent. In most cases the hollows appear as areas of relatively high reflectance by late summer, although in some cases a residual darker area remains.

The hollow features at Karaca Hüyük I, Sarlak Hüyük, Okçu Hüyük II and Kervan Hüyük were visited in early April 1997 to establish whether the variation observed between the mid and late summer images might be caused by the formation of shallow ponds during the early part of the year. The Konya basin receives much of its annual rainfall during the early spring period and sediments at the base of the

hollows were found to be moist at the time this fieldwork was carried out but did not contain standing water. Inspection of the same locations during subsequent fieldwork in August and September showed sediments at the base of the hollows to be dry. On the basis of these observations, the spectral change at mound associated hollows is interpreted as a product of soil moisture conditions, with the prominent appearance of hollows in the June image caused by their waterlogged state in the early part of the year.

While the association between hollow features and archaeological settlement mounds is clear, the function of these features remains to be established. The hollows observed in the northern Jazira may have provided a general purpose surface water resource related to the occupation of the mounds where they are found (Wilkinson pers. comm.). On the Çarsamba fan, culturally modified marl surfaces have been recorded by Boyer at depths of more than 2.5 metres below the modern land surface adjacent to the Neolithic mound at Çatalhöyük East. Sediment cores show that the Neolithic inhabitants of Çatalhöyük removed surface sediments to reach the underlying marl in this area (Roberts et al 1996). This suggests that the arrangement of excavated hollow and tell mound may extend over a considerable period.

In the case of the hollows identified from Landsat data on the Çarsamba fan, it should be noted that not all settlement mounds have associated hollow features. In some instances, these features may be linked to former stream channels. The clearest example of this is at Kervan Hüyük, but other instances include the hollows at Sarlak Hüyük, Okçu Hüyük II, Pirsanlı Hüyük and Erminler Hüyük, suggesting that the hollows at these mounds may have been formed by the enlargement or modification of natural watercourses. A further characteristic of mound associated hollows is that they generally adjoin Hellenistic and later period settlements. This raises the possibility that the hollows visible on the Landsat data may be connected to settlement activity in these periods, and possibly to the quarrying of mudbrick from the lower slopes of earlier tells. Quarrying of this type continues in the modern landscape on the lower western slopes of Sarlak Hüyük I, at Pirsanlı Hüyük and

Samih Hüyük. This observation would not preclude the existence of hollows dating to earlier periods buried beneath later alluvial deposits, as found at Çatalhöyük.

#### 7.4 Approaches to archaeological site detection

The high spectral range and resolution and relatively low spatial resolution of the Landsat TM data made multispectral image classification the obvious approach to the extraction of archaeological features. The spectral range of the SPOT Panchromatic sensor approximates that of the Landsat TM green and red bands (TM bands 2 and 3) in the visible portion of the spectrum, but has better spatial resolution allowing the use of visual interpretation methods. Stratification-based approaches rely on the association between archaeological features and some classifiable characteristic of the modern landscape. Depending on the strength and accuracy of the association involved, it may still be necessary to spend considerable time and effort searching extensive 'site likely' regions before sites are located. The advantage of directly detecting archaeological features is that the features are specifically located, allowing potential archaeological features to be confirmed or eliminated rapidly on the ground. The success of the direct detection approach is dependent on identifying the spectral characteristics of past settlement sites and on isolating these from the background environment.

The mapping available at the start of the project was limited in terms of both its scale and coverage and did not permit the limits of past settlements to be located with sufficient precision to define useful supervised training regions on the image data. Under these conditions it was felt that the only practical approach to the investigation of the highly variable appearance of archaeological mound sites was to visit a large number of archaeological mounds in the field with the purpose of recording their topography and surface cover characteristics. The observations made on the ground at individual mounds could then be compared to their appearance on the satellite imagery on a site-by-site basis with the aim of establishing significant relationships. The mound surveys undertaken in the first fieldwork season were mostly of smaller

mounds, often located in cultivated fields. This combination made it difficult to isolate specific factors affecting the appearance of mounds on the satellite imagery.

In the present project, unsupervised classification was carried out within two 1335 x 1460 pixel image subsets of the June and September Landsat TM scenes. The limits of the two subsets were matched by inspection, but the subsets were not registered to each other before classification to avoid the spectral degradation produced by the interpolation of data values (section 6.8). The Landsat image subsets extended beyond the limits of the Çarsamba fan study area to include areas of lake bed marl to the north, east and west, and of the bajada zone to the south.

A second consequence of the difficulty of defining supervised image training areas from the available mapping, was that unsupervised classification was explored from an early stage as a possible approach to the multispectral analysis of the Landsat TM data. Unsupervised classification of the two Landsat scenes was performed using the ISODATA (Iterative Self-Organising Data Analysis Technique) algorithm available within the classification module of the ERDAS Imagine digital image processing software package.

ISODATA clustering allows pixels having similar spectral properties to be grouped together through the application of a minimum distance decision rule based on calculation of the spectral distance between the candidate pixel and a set of cluster means, with pixels being assigned to the cluster to which they are closest in multispectral space. The number of clusters to be created is specified by the user at the beginning of the process and a corresponding number of arbitrary mean values for these are assigned in the first iteration of the algorithm. As the clustering process is repeated, the initial position of cluster means is shifted to fit the spectral variation found within the data. The algorithm repeats until the decision parameters set by the user are met. These parameters can be a convergence threshold, in terms of the percentage of pixels whose class values are unchanged following each iteration, or a maximum number of iterations to be performed (*ERDAS Field Guide* 1994: 240-244).



For the purpose of producing a series of mound-related spectral classes, the number of clusters to be identified was set at 50. This value was chosen arbitrarily in the expectation that it would prove sufficiently large to produce a sub-classification of archaeological mound reflectance features. A convergence threshold of 97% and maximum of 15 iterations were set as decision parameters for the clustering process to ensure that the process did not terminate before the possible alternative classifications were thoroughly explored. Data from all six non-thermal Landsat TM bands was used in the classification.

The ISODATA classification resulted in the generation of a series of mound associated classes that could be used to locate archaeological sites. The graph in Figure 7.9 shows the performance of three classes found to be useful in locating archaeological sites. The spectral profiles of these classes are plotted against reflectance profiles obtained at open and enclosed mounds in Landsat TM bands 1 and 2. The value of individual classes in locating archaeological sites was assessed by their effectiveness in classifying known archaeological mound sites and by the proportion of non-mound pixels included in the classification. The three classes illustrated in Figure 7.9 represent approximately 6.3% of the area of the September Landsat image subset, a relatively small proportion of the total number of pixels. A feature of the ISODATA classification was that no single 'mound' class was generated. The types of non-mound land covers having similar spectral properties to archaeological features was instructive in terms of identifying the nature of the spectral variation recorded in the different ISODATA classes.

Archaeological settlement mounds were identified more easily in irrigated agricultural fields than on former shoreline ridge or semi-permanent pasture areas. The difficulty of distinguishing between open settlement mounds and semi-permanent pasture are apparent from the data reproduced in Table 7.1.

Signature: pasture\_fan  
 Number of pixels: 6863

Layer	Statistics			
	Mimimum	Maximum	Mean	Sigma
1	115.000	213.000	155.433	8.698
2	57.000	119.000	82.997	5.090
3	71.000	163.000	114.107	7.835
4	55.000	143.000	111.552	5.462
5	39.000	249.000	207.051	10.415
7	23.000	156.000	121.173	11.009

Signature: open\_mounds  
 Number of pixels: 2051

Layer	Statistics			
	Mimimum	Maximum	Mean	Sigma
1	96.000	214.000	149.908	19.597
2	46.000	115.000	79.066	10.894
3	41.000	158.000	106.644	16.598
4	71.000	179.000	116.778	10.495
5	67.000	255.000	184.061	29.755
7	25.000	156.000	101.304	23.925

Table 7.1 Distribution of brightness values for open settlement mounds and pasture areas on the Çarsamba fan.

Multispectral image enhancement techniques designed for vegetation monitoring applications were found to improve the visibility of open type archaeological mounds in situations of low spectral contrast with surrounding land covers. The simplest image enhancement techniques found to be effective in this context were the Vegetation Index, which is calculated using TM band 4 minus TM band 3 (Tucker 1979) and the Normalised Difference Vegetation Index or NDVI, calculated using  $\text{TM band 4} - \text{TM band 3} / \text{TM band 4} + \text{TM band 3}$  (Jensen 1986). The Vegetation Index and NDVI amplify the variation recorded at red and reflective infrared wavelengths, which includes the characteristic spectral absorption feature or 'red shift' observed in the reflectance of green plants between approximately 0.60 and 0.80  $\mu\text{m}$ .

The significance of spectral variation in the red and reflective infrared region in situations where open type mounds are located in pasture land covers can be seen from the values in Table 7.1. Mean brightness values recorded for open mounds

show higher reflectance in TM band 3 than in TM band 4, while the reverse is found for pasture land covers. The vegetation index and NDVI are effective in isolating this variation, although the absolute size of the effect in the raw data is relatively small.

More complex image enhancements based on transformation techniques were also applied to the Landsat data in an attempt to increase the visibility of archaeological features. Both Principal Components and Tasselled Cap transformations (Kauth and Thomas 1976, Taylor 1977, Crisp and Kauth 1986, Richards 1993) were found to be effective in this respect. Principal Component Analysis (PCA) has been established as a useful technique for image enhancement in many remote sensing applications. An important property of the Principal Component transformation in terms of image enhancement is that it reduces the dimensionality of complex multispectral image data, facilitating interpretation. This reduction in dimensionality is obtained through the compaction of redundancy, in the form of correlation between the original multispectral data bands. The transformed data are projected according to new axes defined in spectral space to provide a new set of data bands which are often found to be more easily interpreted than the source data (Jensen 1986).

The Tasselled Cap transformation was originally designed to optimise Landsat MSS data for the purpose of studying changes in vegetation covers, although the technique has since been extended for use with Landsat TM data (Kauth and Thomas 1976, Crist and Kauth 1986, Jensen 1986). The Tasselled Cap transform rotates the principal axes of the TM data in spectral space to derive a new data structure designed to maximise the visibility of the reflectance and absorption features important in vegetation studies (Crist and Kauth 1986). The first three orthogonal data axes generated by the Tasselled Cap transform are termed Brightness, Greenness and Wetness. These three data axes can be define two planes, the Soil and Vegetation planes, in spectral space (Jensen 1986).

An advantage with the PCA and Tasselled Cap transforms when compared to the index based enhancement methods previously described, is that the transforms use information in all the non thermal TM bands. The observed reflectance

characteristics of enclosed and open archaeological mound types in Landsat TM bands 5 and 7 (figure 7.4), suggest that reflectance features in the mid infrared region will contribute significant information to the classification of mound types. While the vegetation indices (R/IR, NDVI) are found to be effective in increasing the visibility of mounds, these forms of image enhancement do not use spectral information recorded at mid infrared wavelengths which is of potential value in soil and vegetation analysis (section 6.7). As the reflectance of archaeological mounds is produced by a combination of vegetation and bare soil components the inclusion of data from bands useful in the discrimination of both soil and vegetation conditions is clearly desirable.

In view of the difficulty of extracting mound locations in some background land cover conditions, it was decided to investigate whether classification might be improved through preprocessing of the Landsat data prior to the classification being performed. A second ISODATA classification was carried out according to the same parameters as were used in the original classification, but using data processed using the Tasselled Cap transform.

Figure 7.10 illustrates the performance of the two ISODATA classifications with respect to identification of features at the large archaeological mound site of Turkmenkarahöyük. The true colour view of Turkmenkarahöyük in figure 7.10 was created using a 3,2,1 assignment of the raw TM band data for comparison purposes. The two thematic views in figure 7.10 were generated by ISODATA classification of the raw Landsat data and of data spectrally enhanced using the Tasselled Cap transform prior to clustering. Spectral classes considered to be useful in the identification of archaeological features are highlighted by the use of colour in the two thematic views.

Comparison of the thematic views in figure 7.10 shows that classification of the raw data obtained better discrimination of the different land cover sub types present on the mound. The raw band data classification produced four mound associated classes which are effective in distinguishing between the upper mound surfaces, slopes and

vegetated lower mound areas. The classification produced from the Tasselled Cap data was able to discriminate only two land cover sub types at the site, the first corresponding to upper mound surfaces and predominantly bare soil areas and the second to the more densely vegetated lower mound areas. Both classification schemes exclude the steeply sloping area of the north western mound that would be in shadow or illuminated at a very shallow angle at the time of the overpass of the TM sensor (9.30am local time). A scale contour map of Turkmenkarahöyük (contour interval 1 metre) is reproduced in figure 7.10 to illustrate the topographic layout of the site for comparison with the image data.

Ground observations suggest that reflectance characteristics in the visible region might be used to distinguish between decomposed mudbrick material and alluvial sediments. In situations where the edges of settlement mounds are exposed by ploughing, the appearance of the weathered mudbrick sediments is found to contrast quite strongly with the surrounding alluvium, being lighter in colour. This contrast between mound material and alluvium was found to be visible on the SPOT Panchromatic data, where the location of cultivated mounds is apparent from their shape and brighter appearance under bare soil conditions.

In order to measure the level of variation in brightness between archaeological sediments and cultivated alluvial soils, a series of brightness values were obtained from the December SPOT Pan scene at cultivated mound locations and compared with those obtained from the surrounding fields. Mound values were found to range from a minimum of 29 to a maximum of 51, with a mean value of 38.3 ( $n = 1237$  pixels, sigma 3.5). Values for bare soils in the surrounding fields ranged from a minimum of 22 to a maximum of 38, with a mean value of 27.7 ( $n = 6035$ , sigma 2.1). The size of the variation in mean brightness values, about 10 points, is sufficient to allow potential mound locations to be identified from manual inspection of the data in the December SPOT scene.

SPOT Pan data for the site of Turkmenkarahöyük are illustrated in figure 7.11. The contrast between the lighter mound sediments and surrounding soil covers is very

apparent in this image. The SPOT data provide a detailed representation of the major topographic features of the site and there is considerable contrast between the ridges and upper mound surfaces of the site and the gully systems formed in its eastern and southern slopes. An extensive low angled fan of re-deposited mound material is also visible extending from the north-eastern edge of the site, a feature which is not apparent from the Landsat data. The level of topographic detail available from the SPOT Panchromatic channel data in figure 7.11 can be compared with views of the same site obtained by the Landsat TM sensor. The level of additional information provided by the SPOT Pan data is not nearly so great as might perhaps be anticipated from differences in the nominal spatial resolution of the two sensors (i.e. 10 metres and 28.5 metres). The Landsat TM data captures the main topographic elements of the site effectively because of the good spectral contrast that is obtained between the bare soil of the ridge and upper mound surfaces and the vegetated slopes and gully areas.

The thematic classification schemes illustrated in figures 7.10 and 7.11 were used by the author to locate archaeological features in the field as part of an archaeological survey project directed by Dr Douglas Baird of the University of Liverpool. In this application, thematic imagery produced by the classification of Landsat TM data and hardcopy printouts of raw SPOT Panchromatic imagery were taken into the field and successfully used to locate previously unrecorded sites and to establish the shape and extent of artifact scatters surrounding known archaeological mound sites. Six previously unrecorded mounds were located within the Çarsamba study area from classified Landsat TM imagery in the course of these field trials; Karkin Mezarlik II, Kizil III, Sarlak II, Deli Ali, Musluk Hüyük and Üçhüyükler III (the map coordinates of these and other sites referenced in the text, are listed in Appendix I). Figure 7.11 shows the appearance of the mound at Musluk Hüyük on the SPOT Panchromatic and classified Landsat TM data.



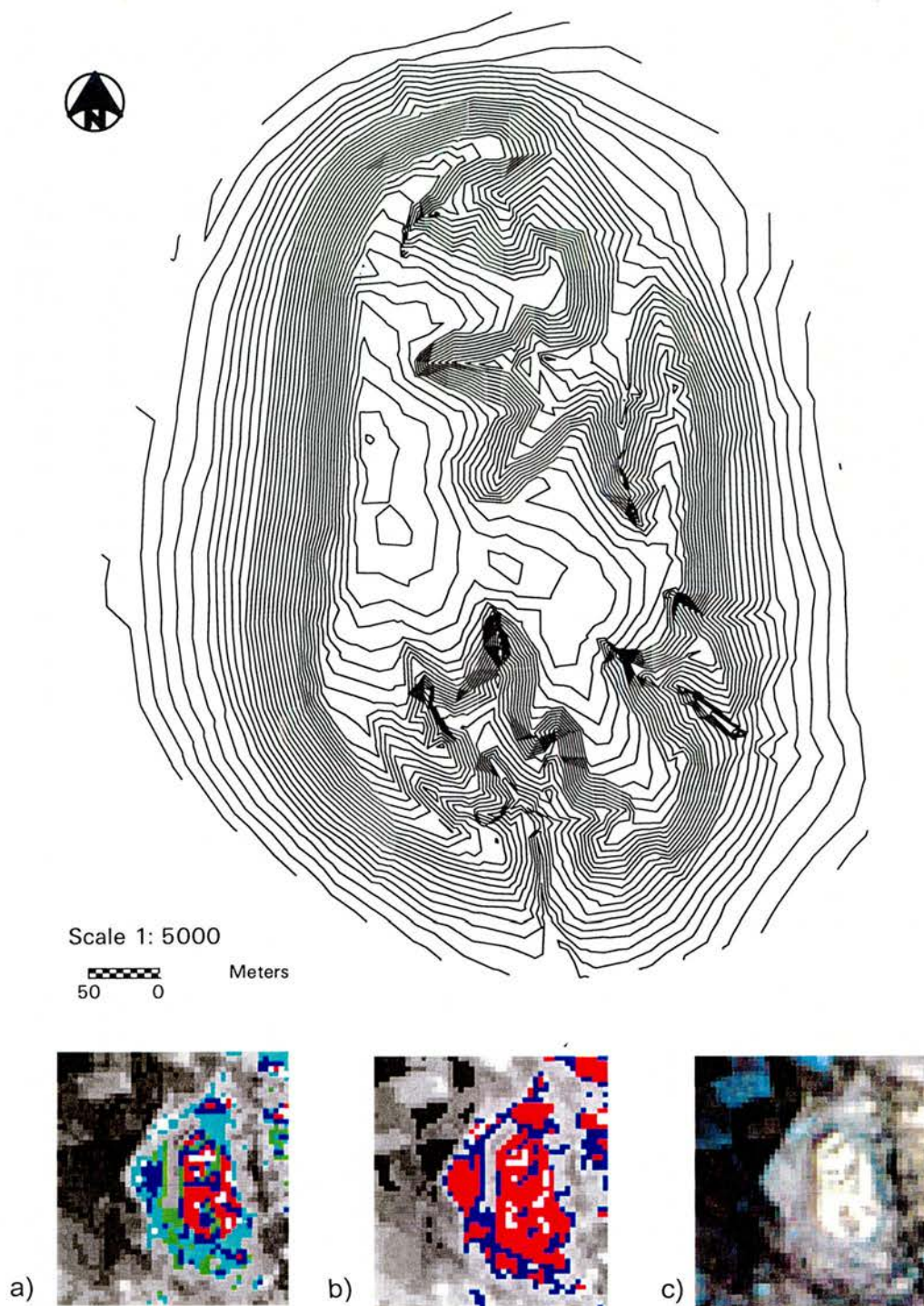


Figure 7.9 Top: Contour map of the Turkmenkarahoyuk settlement mound (contour interval 1 metre) showing complex ridge and erosion gully topography. Image chips showing ISODATA classifications from raw TM data (a), Tasseled Cap transformed data (b). Compare with natural colour composite (bands 3,2,1) view of same area (c).

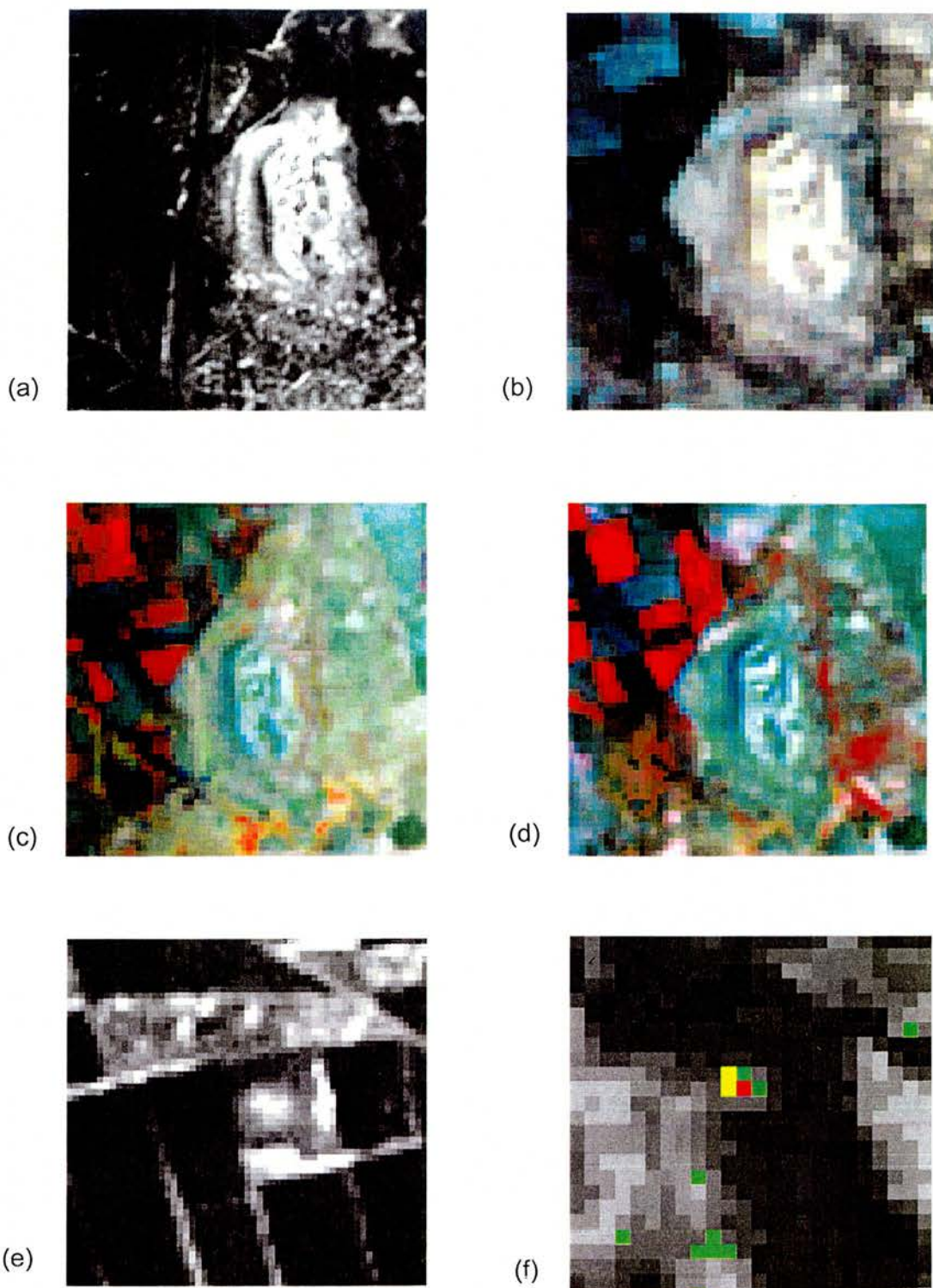


Figure 7.10 Top: SPOT Panchromatic (a) and Landsat TM (b) views of settlement mound at Turkmenkarahoyuk. Middle: Landsat TM false colour (bands 4,5,3) views of same area for June (c) and September (d). Lower: SPOT Panchromatic subset showing low mound of Musluk Huyuk under bare soil conditions (e), Landsat TM classified thematic image of same area (f). Coloured pixels indicate mound-associated spectral classes.



The previously unrecorded mounds identified from the imagery represent a success rate of approximately 30% in terms of the total number of possible mound locations that were investigated. Features wrongly identified as archaeological mounds included outcrops of lake bed marl in cultivated fields, sand and clay dunes and erosion features on palaeoshoreline ridge soils. The benefits of the direct detection methodology were apparent in terms of the relatively small amount of time required to check each potential mound location, effectively the time taken to travel to a location and walk over it. The unobtrusive character of the mounds located from the satellite data suggests that the direct detection of archaeological settlements from satellite imagery can contribute significant additional information over what would be obtained by conventional survey alone.

The results obtained at Turkmenkarahöyük suggested that the spectral enhancement of the raw TM band data prior to classification had the effect of reducing the effectiveness of the classification in discriminating between different types of mound surface covers. Although the Tasselled Cap data was less effective in this application, a comparison of the performance of the two classifications across an area containing a number of known mounds in the eastern fan demonstrated that the Tasselled Cap based classification could provide a robust two-class classification across a wider range of mound sites.

In this test, fewer pixels were found to be classified to mound associated classes in the thematic image obtained from classification of the raw data than in the classified Tasselled Cap data, although the positions of recorded mounds were identified in both scenes. Most mounds were identified to a single 'mound slope' class in the raw data thematic image whereas the Tasselled Cap classification gave a two-class identification for the same sites. The Tasselled Cap thematic image erroneously identified groups of pasture land cover pixels to a mound associated 'vegetation' class however.

Despite the increase in confusion errors between non-archaeological land covers and 'vegetated slope' mound land covers, the Tasselled Cap based classification identified

additional areas that were of potential archaeological interest, including historically abandoned mudbrick structures. In archaeological prospection as in other remote sensing applications, some compromise appears to be necessary with regard to the inclusiveness of a classification and the level of confusion error it contains.

## 7.5 Factors in the appearance of mounds on Landsat TM and SPOT Panchromatic imagery

Archaeological settlements form a single information class, but are identified to three types according to their appearance on Landsat TM and SPOT Pan data. The characteristics of the three mound types; open uncultivated, enclosed and cultivated, relate to modern patterns of land use and vegetation cover. Within the open uncultivated and enclosed types, multiple spectral sub-classes can be identified, including a general 'mound' class, a 'vegetation' class and a 'bare soil' class. The fact that multiple spectral classes can be identified and matched to local variations in vegetation cover at individual mound sites demonstrates that the spatial and spectral resolution of Landsat TM is more than adequate for archaeological detection applications. A more important factor than spatial resolution is the level of spectral contrast between past settlements and their backgrounds and the amount of variation introduced by pixel mixing effects at smaller sites.

Landsat TM thermal band data is generally discarded for land use classification applications, but is found to be potentially useful in the detection of open uncultivated and enclosed sites. High DN values occur in the TM band 6 data recorded over archaeological sites. Hollows adjacent to some settlement mound sites are also visible in the thermal band data, while larger mounds tend to appear bright in comparison to surrounding areas. The relatively low spatial resolution of the thermal band data recorded by the TM sensor rules out its use for the detection of smaller settlements. The improved 50 metre spatial resolution of the thermal data collected by the new ETM+ sensor on board Landsat 7 should allow archaeological detection applications using thermal data to be extended.

The nature of the location task changes at seasonal and annual scales. The most effective archaeological detection approach will exploit this temporal variation in the visibility of sites. Multidate image analysis is an effective strategy because the spectral characteristics of enclosed and open uncultivated archaeological mounds display far less variability than the surrounding intensively farmed landscape. The SPOT Pan scene used in the project was acquired during December when fields are cleared of crops. Under bare soil conditions, clear variation can be observed between mounds and background soils. The higher spatial resolution of the SPOT Pan data was also valuable in reducing mixed pixel effects. At smaller sites, the higher spatial resolution of SPOT HRV multispectral data would be expected to produce better results than Landsat TM within the wavelength range it covers (approximately equivalent to Landsat TM data green through reflective infrared data bands, 0.50-0.89  $\mu\text{m}$ ).

The smaller IFOV of the SPOT Panchromatic data is potentially valuable in many aspects of archaeological survey work, however, its relatively coarse spectral resolution means that it can be difficult to locate even quite large sites. A factor affecting the visibility of archaeological mound sites on SPOT Pan data may be the position of the SPOT Panchromatic channel in the 0.51 to 0.73  $\mu\text{m}$  region. Open type mounds and pasture land covers are observed to have almost identical reflectance characteristics across much of this range.

With regard to other factors affecting the visibility of archaeological mounds on satellite data, the occupation dates of a site do not appear to influence its reflectance characteristics. The appearance of archaeological mounds on satellite data is a product of a combination of bare soil and vegetation components with the relative contribution of each varying according to the nature and density of vegetation cover. Illumination effects, i.e. the differential illumination of slopes according to their aspect, also appear to be unimportant at most archaeological mound, although they are apparent at some larger mounds. Differences in vegetation covers appear to be responsible for much of the variation found between the reflectance characteristics of

open and enclosed mounds. Patterns of increased plant spacing and reduction in plant size from the lower to upper slopes can be linked to local variation in the reflectance observed at mounds, and are especially prominent at larger mounds, as for example at Turkmenkarahöyük.



## Chapter 8: Archaeology, remote sensing and GIS

### 8.1 Archaeology, remote sensing and GIS

It has been suggested that GIS should not be considered a tool but rather as a means of creating an environment within which to explore ideas as part of a 'GIS approach' (Gillings and Sbonias 1999: 36). This clearly challenges the perspective of early archaeological users who considered GIS, and other related new technologies including digital image processing, precisely as tools capable of archaeological applications (Farley 1988). The perspective of the present research is that GIS technology can be used to create environments in which ideas can be explored without the need to invoke a specialized 'GIS approach'. The objective has therefore not been to pursue a remote sensing or GIS approach to the archaeological record, but to implement a traditional programme of archaeological research (i.e. regional scale archaeological survey and the interpretation of the past settlement record) with the support of remote sensing and GIS technology.

It has been observed that sophisticated technology cannot overcome basic deficiencies in the archaeological record (Stancic et al 1995: 164) and this has been true of the present research. The scope for GIS in the present project has generally been constrained not by the capabilities of the technology, but by the limitations of the archaeological information that is available. The dating scheme outlined in table 2.1, illustrates a major source of uncertainty in the analysis of the settlement history of the Çarşamba fan, namely the coarseness of the available periodised dating framework. The likelihood that some reconstructed settlement distributions are diachronic patterns is apparent from the length of some of the archaeologically defined periods used in the analysis. The Early Bronze Age I and II period, for example, may span a thousand years or more.

Despite the problems that appear inherent in archaeological data, the suggestion that GIS technology may ultimately restrict rather than promote the development of archaeological analysis (Gaffney et al 1995: 41) seems overly pessimistic. Even

under conditions of poor dating resolution and probable recovery bias, the value of GIS-based analysis as a tool to isolate trends and indicate possible avenues for future research is clear. There are also compelling practical benefits available from GIS technology in terms of spatial data management.

Integrated spatial data management is a fundamental element of GIS functionality, but its practical value should not be underestimated in the context of planning and implementing a programme of archaeological fieldwork. In the course of fieldwork for present project for example, digital map products generated from satellite imagery held within the project GIS enabled the orientation of survey teams working beyond the limits of the available conventional map base. When the difficulty of accomplishing such 'low level' spatial data manipulation tasks outside the GIS environment is considered, the fact that this technology is only now beginning to be routinely used in archaeological surveys is remarkable.

In recent years the traditional technical and cost barriers to the uptake of GIS have become reduced to an extent that could not have been anticipated even five years ago. Specific developments that have been important in this respect include the advent of cheap, powerful CPUs, large capacity hard disk drives, and CD writers. These technical innovations have been instrumental in bringing the practical manipulation and management of large data files within the scope of modest desktop and portable computing platforms, making them accessible to the smallest archaeological projects.

Many archaeological applications of GIS emphasize some form of landscape stratification methodology. This characterization of the wider landscape into zones with a greater or lesser likelihood of containing archaeological features is a direct reflection of a classic GIS application outside of archaeology, the optimal location of a proposed amenity or structure as part of the planning process. Considered from this perspective, even more recent 'reflexive' archaeological applications can be regarded as technically refinements of the same methodology. Viewsheds, sophisticated

photo-realistic visualizations and cost-effort surfaces, are recognizably adaptations of civil engineering applications.

The analysis of archaeological distributions is often undertaken as part of a formal predictive modelling effort (e.g. van Dalen 1999). In the present project, reconstructed distributions were not investigated for predictive modelling purposes but to explore differences in the character of settled landscapes at different times in the history of the Çarşamba fan. The idea that the analysis of settlement sequences can yield insights into the processes underlying settlement change is not new (Adams 1965), but its implementation within the GIS environment represents a logical development.

Earlier it was noted that the analysis of archaeological settlement distributions differed from the analysis of modern distributions because of the incomplete and biased nature of archaeological data. In the case of the present research, significant recovery bias is introduced by the burial of the settlement remains by later alluvial deposits. Other bias factors are also apparent however, including variation in the archaeological visibility of materials between different periods and the influence of the transition from highly nucleated settlements to more open forms of settlement layout. The fact that reconstructed settlement distributions are often not ‘snap shots’ of settlement systems but represent compound views of the settlement activity that occurred over a substantial time period also has implications for spatial analysis, to the extent that most spatial analysis techniques are essentially synchronic (Adams 1972: 745).

Despite these factors, patterns are clearly present in the reconstructed archaeological distributions that are unlikely to be explained by differential recovery and visibility factors. Robust analytical methods were purposely chosen to reduce sensitivity to missing or wrongly assigned data. These techniques were successful in identifying patterns of occupation and abandonment in the eastern fan and of changes in the focus and intensity of settlement elsewhere across the fan in different periods. These patterns are interpreted as the product of changes in land use and as the response to

changing physical environments on the fan. This theme is explored further in the settlement history below.

The use of satellite remote sensing on the Çarşamba fan has highlighted several aspects of this technology. An important finding is that earth observation data can be employed relatively inexpensively. The latest and most expensive data are not necessarily required for archaeological applications where the features of interest are generally fixed locations. Archived imagery not only offers a significant cost saving over the most recently acquired data, it can also provide information on historical land use including patterns of field clearance or agricultural practices that impact the archaeological resource.

The remote sensing component of the research was successful in isolating sources of spectral characteristics at mound settlements and in the specific detection of previously unrecorded settlements. The extensive remit of the Konya Plain Survey presented an opportunity to integrate remote sensing research with the field investigation of archaeological sites of all sizes and to investigate the surface characteristics of more than 150 archaeological settlement sites on the ground.

Simple remote sensing approaches including change detection using multi-date imagery and unsupervised multi-spectral classification can be highly effective. The specific or direct detection of archaeological features does not require high spatial resolution imagery. Both Landsat and SPOT imagery proved capable of revealing features that were not readily visible on the ground. At Kumoç Hüyük, for example, an extension to the main mound was identified from satellite imagery *after* field collections and a contour survey were made at the site.

Debate about the practical limitations of satellite imagery for archaeological detection has sometimes emphasised spatial resolution issues to the exclusion of factors in the spectral domain. In the case of tell sites measuring over a hectare in size, the spatial resolution of imagery acquired by the SPOT and Landsat TM sensors should be more than adequate for detection purposes (Fuller et al. 1989). In practice,

it was frequently possible to predict significant information about an archaeological site from the remote sensing data, including its size, shape and surface characteristics. It is useful to distinguish between the level of information necessary for detection and the type of detailed view that might be obtained from an aerial photograph or similar image. In Chapter 6 that was observed that the 'spatial resolution' of both the Landsat Thematic Mapper and the SPOT sensors are theoretically more than adequate for the detection of large archaeological targets such as tell sites. The implication is that efforts to detect tell sites should focus on the spectral characteristics of tells and their background settings and the conclusion must be that spectral separation from background is at least as important as obtaining better spatial resolution.

Because of the importance of the spectral domain in detecting archaeological features, it is important to look at multi-spectral data. Multi-date imagery can improve detection because the spectral characteristics of archaeological features and their surroundings change over time. There may be times during which features are more readily distinguished from their backgrounds. Multi-date imagery allows a wide range of visibility conditions to be investigated and can help the analyst highlight factors that are important in the appearance of archaeological features on satellite imagery. On the Çarşamba fan, features of potential interest were studied on SPOT and Landsat data, in different band combinations and using raw and classified imagery. The features selected for investigation on the ground were those that appeared most similar to known archaeological features across a range of viewing conditions.

Remote sensing data were found to have significant non-detection applications in the planning of fieldwork and for orientation in the field, including the use of subset image printouts for navigation and imagery rectified to provide geographic/spatial control networks that could be used alongside handheld GPS units. In terms of the targeting of archaeological survey teams, the specific or direct detection of archaeological features proved a more powerful technique than the designation of extensive 'site-likely' zones using landscape classification methods. The objective of

the remote sensing component of the project was therefore to develop techniques for the direct detection of archaeological features, rather than to reproduce the landscape classification methodologies that are more generally applied in archaeological contexts.

The presence of hollow features associated with mounds was revealed from inspection of the satellite imagery. Similar hollows are recorded at mounds in other areas of the Near East (e.g. Wilkinson 1990), but the presence of these features has not previously been noted at mounds in the Konya basin. Settlement mounds appear as brighter areas in the thermal band of the Landsat TM sensor, a feature possibly related to the lower moisture content of raised mounds or their sparse vegetation cover - although this was not investigated. While the possibilities of the Landsat TM data have by no means been exhaustively explored, the prospects for the detection of archaeological features in similar environments using the current generation of earth observation sensors must be regarded as favourable in the light of the results obtained with this relatively low-resolution image data.

## 8.2 A settlement history of the Çarşamba fan

Sediment cores from the Konya basin contain evidence of new plant resources and climatic amelioration several millennia before the earliest local archaeological evidence for proto-agriculture (Reed et al 1999). This evidence, and the fact that the last major reduction in Konya paleolake levels occurred well before the end of the Pleistocene, suggests that the basin floor was accessible to local populations for some millennia prior to the first settlement at Çatalhöyük. Recently discovered archaeological evidence of early prehistoric occupation on the Çarşamba fan, and at Pınarbasi to the south of the Hotamis depression, confirm that human groups were present in the Konya basin before the Neolithic.

Cohen (1970) proposed that the distribution of soils surrounding Çatalhöyük today is essentially the same as at the time the mounds were occupied and that modern soils maps could therefore be used to assess the contemporary environment and



agricultural potential of the area surrounding the Neolithic settlement. In particular, Cohen suggested that a location at the southern margin of an area of fertile backswamp soils was intentionally chosen for the settlement (Cohen 1970: 132).

Subsequent geomorphological investigations have discounted Cohen's assessment and it has been demonstrated that the backswamp soils surrounding Çatalhöyük actually postdate the Neolithic by some millennia (Roberts 1982). Land surfaces contemporary with the early settlement at Çatalhöyük have been found buried to a depth of more than two metres beneath later alluvium in the vicinity of the site (Roberts et al 1997, Boyer 1999). The Çarşamba alluvial fan would have been steeper and smaller at the time that Çatalhöyük was occupied and the original location of the settlement now seems likely to have been close to the margin of the contemporary fan. The deltaic deposits formed by the Çarşamba as it flowed into lake Konya during the Pleistocene would have been uncovered from the final permanent drop in lake levels at ca. 17,000 BP.

The presence of settlements towards the edges of the Konya plain may reflect the increasing dessication of the central areas of the Konya basin, making them less attractive to early prehistoric groups, rather than the occupation of areas uncovered by lake retreat as Cohen proposed (Roberts 1980: 230-231). Under such conditions, the mosaic habitats where rivers entered the basin and along the margins of secondary depressions on the basin floor, which contained freshwater bodies, would be logical focii for settlement. Traces of early prehistoric settlement have recently been identified as components within mixed-date assemblages at settlement mounds further towards the centre of the basin (Baird 1996).

Çatalhöyük can no longer be considered the starting point for settlement of the Konya basin, as has been assumed by some authors, but is evidently a development from some earlier pattern of human settlement. By the early Neolithic, contemporary with the aceramic occupation at Can Hasan III around the 8<sup>th</sup> Millennium BC calibrated, the floor of the Konya basin would have been generally dry with the exception of the small lakes and marshes within the secondary depressions.

Sediment cores indicate that the Çarşamba was depositing alluvial sediments throughout the Neolithic in the vicinity of Çatalhöyük in the central area of the modern fan, probably as the result of seasonal variations in river flow producing regular overbank flood events during the spring season. Early populations on the Konya plain may already have created an anthropogenic steppe environment before the end of the Neolithic through the clearance of open forest cover, perhaps against a background of naturally declining regeneration rates.

Under the conditions outlined above, the inhabitants of Çatalhöyük would be ideally placed to develop techniques of agricultural food production. It seems likely that the intensive and sophisticated irrigation practices of later periods have their origins in the increased agricultural specialisation occurring at Çatalhöyük and other settlements at this time, centred on the exploitation of natural seasonal flooding regimes.

The unique size and cultural complexity of the Neolithic settlement at Çatalhöyük indicate that the site was of regional significance, but an understanding of how this large settlement functioned with regard to the wider population of the Konya basin has yet to emerge.

Çatalhöyük clearly remains a focus for settlement in the Early Chalcolithic, as evidenced by the relatively large size of the West mound, but is abandoned by the beginning of the Later Chalcolithic around 4500 BC. There is evidence of a shift in the distribution of populations on the fan between the Early and Later Chalcolithic that may relate to changes in the alluvial regime of the Çarşamba during this interval. In particular, a new settlement sub-locus appears in the north-western fan while settlements become abandoned in the central fan at Çatalhöyük West, Musalar Hüyük and Seyithan. A north-south linear arrangement of settlements running from south of the shoreline spit, may indicate the presence of a channel to the west of the modern course of the Çarşamba.

The settlement patterns reconstructed from surface survey reveal striking differences between the Later Chalcolithic and the Early Bronze I and II periods. Settlement in the Early Bronze period is both more intensive and more extensive than in the preceding Later Chalcolithic. There appear to be two main foci in the Early Bronze I and II period, one in the northern fan and one to the south of the shoreline spit, with the area directly north of the shoreline spit evidently devoid of settlement. The marked increase in settlement density is interpreted as evidence of intensive agricultural land use during the Early Bronze I and II period.

Adams noted that the first large towns in the Diyala region of Iraq were placed on separate branches of a stream, or at least on separate reaches of a long continuous branch rather than at the nodal points of an irrigation channel network. The fact that these settlements were poorly located for direct control of irrigation water led Adams to conclude that they were located for commercial activity (Adams 1965: 41). Aspects of the Early Bronze I and II settlement distribution resemble those found by Adams. In particular, the distribution of the large settlements at Samik, Kerhane and Turkmenkarahöyük, fits a pattern of relatively widely spaced population centres located on the distal reaches of a natural stream network. Locations near the edge of the fan hardly facilitate access to the most productive agricultural soils but would be convenient for interaction with regional trading routes crossing the Konya basin south of the Tuz Gölü.

Areas of reduced settlement density during the Early Bronze I and II period can be seen clearly from the kernel density estimate in figure 5.9. The first of these areas corresponds closely to the younger backswamp soils, believed to have formed under conditions of permanent or semi permanent inundation. The second area of reduced settlement density is located at the north-eastern limit of the Çarşamba alluvium, south of the modern village of Ovakavagi. The absence of settlement in these two areas of the fan may relate to their lower agricultural potential. It is suggested that these areas were unsuitable for settlement and agriculture during the Early Bronze I and II period, perhaps because of waterlogging. Both areas are moderately salt affected in the modern landscape.

While the largest Early Bronze I and II settlements are spaced regularly with respect to each other, the smaller settlements do not form a clear symmetrical formation around these main population centres, as might be predicted by classic spatial-economic models such as Cristaller's K-landscapes. A possible interpretation is that the settlements within these clusters are not located for most efficient access to the larger settlements, but to maximise the agricultural yields from areas of the fan that could be most readily and reliably irrigated.

If the clusters within the Early Bronze settlement distribution are centres for agricultural production on the fan, it is appropriate to consider scenarios in which the productivity of these intensively cultivated areas would be reduced as a potential factor in the collapse of local populations in the later Early Bronze Age. A situation in which local population levels and wider politico-economic structures had become highly leveraged on the agricultural surpluses from these key areas might be envisaged.

Using the basic population and agricultural productivity models discussed earlier, it is possible to perform some calculations for the reconstructed Bronze Age settlement distribution. If all recorded Early Bronze I and II settlements were contemporaneous and the population density at each is estimated at 150 persons/hectare, the Early Bronze I and II population of the fan may have been as high as 26,000 persons, with almost half this number living in the five largest settlements. Applying an annual calorific requirement of 285 kg./person of unmilled wheat, i.e. between the estimates suggested by Hillman (1973b) and Wilkinson et al (1996:21), and yields under low-intensity irrigation conditions of 1001 kg./hectare (110 kg./dönüm - 9%), approximately 74 km<sup>2</sup> of agricultural land, around 16% of the area of the modern fan, would be required to feed a population of this size.

The spacing of settlements in the Early Bronze Age I and II period is rather greater than the minimum required for subsistence agriculture based on these calculations (mean and modal inter-settlement distances to first neighbouring settlements during

the Early Bronze I and II period are 2.4 km. and from 1.5 to 3.5 km. respectively). The mean settlement size in the Early Bronze I and II period conceals a stepped size distribution in which settlement size is distributed about local means of 1.5 and 4.5 hectares, implying populations of between 200 and 700 persons. The largest settlements are obvious exceptions, ranging from 10 to over 20 hectares in size and with populations varying from perhaps 1,500 to more than 3,000 persons.

The scale of the transition between the Early Bronze Age I and II and Early Bronze III settlement distributions is dramatic. Unfortunately, the timescale over which this transition takes place cannot be established from the available archaeological evidence. Mellaart envisaged a sudden collapse in populations across the Konya plain (Mellaart 1963). The presence of 'burnt layers' at Karaca I, Kizlar Hüyük, Kerhane Hüyük, Erminler Hüyük, Samih Hüyük and Sarlak Hüyük I is cited as evidence for the destruction of these sites at the end of the Early Bronze II period (Mellaart 1963: 209-210).

The implication of such a rapid transition is a catastrophic situation, in which local populations would have been reduced by perhaps 90% at the same time as the agricultural production of the fan is lost. However, given the poor dating resolution presently available from typological analysis of the ceramic evidence, it is equally possible that settlement 'collapse' occurred in a more gradual fashion. An alternative to Mellaart's Luvian invasion hypothesis might be a progressive transition from a condition of high population densities and intensive agricultural land use to one of near abandonment by the Early Bronze Age III period.

Factors in the abandonment of the Çarşamba fan after the Early Bronze II period remain open to speculation. If the Luvian invasion hypothesis can be set temporarily aside, the most compelling alternative explanation would appear to be environmental degradation affecting the agricultural potential of the fan during, or towards the end of, the Early Bronze II period. Environmental degradation may account for the collapse in settlement numbers, but any such explanation would need to

accommodate the continued occupation at Karahöyük Konya on the adjacent Meram fan (Baird 1997: 13).

The abandonment of the Çarşamba fan can be reconciled with the continued occupation of adjacent areas, if environmental degradation is specific to the Çarşamba catchment rather than the consequence of deteriorating regional climate. Roberts et al (1996) note that the onset of renewed alluviation on the Çarşamba fan during the late Holocene may relate to Bronze Age and later cultural modification of the Çarşamba catchment leading to increased soil erosion (Roberts et al 1996: 36). Increased widespread flooding could make irrigation agriculture impractical.

An alternative possible explanation, is the entrenchment of stream channels on the Çarşamba fan itself. The human modification of natural stream channels, through straightening and clearing and construction of canals, has been implicated in the onset of stream channel entrenchment in semi-arid environments (Waters 1991: 155-156). This scenario is perhaps more consistent with the palaeoclimatic evidence for a mid-Holocene hiatus in alluvial activity and with the presence of relic channels incised into the lower alluvial units of the fan and capped by late Holocene sediments (e.g. Roberts et al 1996). Episodic drought and stream channel entrenchment have been linked to population fluctuations among prehistoric Anasazi agriculturalists in the southwestern United States (Euler et al 1979, Dean et al 1985, Karlstrom 1988, Larson et al 1996).

The pattern of Early Bronze II settlement abandonment could be of value in interpreting the nature of the transition in settlement distributions observed following the mid-third millennium BC (e.g. Karlstrom 1988, Clement and Mosely 1991). However, considerable improvements in the dating of Early Bronze settlement remains would be needed before patterns of abandonment and possible agricultural land loss could be established on the fan. Whatever the timescale of abandonment, the absence of settlement on the Çarşamba fan by the mid-third millennium BC would be expected to have wider implications to the extent that substantial surpluses



from this important agricultural area would no longer form a part of the regional economy.

The reconstruction of patterns of settlement in the Early Bronze Age III is complicated by the lack of knowledge of local ceramic repertoires during this period. An important consideration is that Early Bronze Age III ceramics may include stylistic features that are also found in the preceding EBA II and subsequent Second Millennium BC periods. This situation hampers the reliable detection of Early Bronze Age III occupation phases within mixed-date ceramic assemblages.

Despite these difficulties, some features of settlement distributions in the Early Bronze Age III period can be identified. The first and most dramatic impression of the Early Bronze Age III settlement distribution when compared to that of the preceding Early Bronze Age I and II, is the huge reduction in settlement numbers. Settlement continues into the Early Bronze III period at Konya Karahöyük. It seems possible that this settlement continued to operate as commercial or trading centre within pre-existing trading networks after intensive agricultural production was abandoned on the Çarşamba fan.

By the second millennium BC, the large former Early Bronze I and II settlements at Seyithan, Sarlak, Samih Huyuk and Kerhane Hüyük are again important population centres. This immense mound occupies a prominent position towards the apex of the Çarşamba fan. This pattern of second millennium reoccupation on the fan falls short of a return to the intensive agricultural land use of the Early Bronze I and II period. The settlement landscape of the second millennium BC suggests that populations are highly aggregated within large urban centres and that the number of persons living on the fan is much reduced from the Early Bronze I and II period. A few smaller settlements are identified to this period, as at Kinikçi Hüyük and Kartaltömegi I.

In second millennium Anatolia, a principal form of economic activity involved trade between a network of large emporia or *Wabartum* (Kuhrt 1995: 92-95). The Konya - Ereğli basin would have been traversed by regional trading networks, as Karahöyük

Konya and Aemhöyük emerged as regional trading centres in this period. Archaeological evidence from the Assyrian colony at Kultepe Kanesh shows that long distance trade was flourishing between 2000 - 1600 BC (Ozgu 1963, Ozgu 1986). The city of *Purushanda* mentioned on clay tablets from Kultepe Kanesh is thought to be either Aemhöyük or Karahöyük Konya.

Crisis and political change characterise the Levant, southern Anatolia and upper Mesopotamia in the late first and early second millennia BC. Within Anatolia, this period saw the destruction of major cities at the heart of the Hittite state within the arc of the Halys river, at Hattusas, Alaca Höyük, Masat and Alishar Höyük in a ‘*brandkatastrophe*’ dated to around 1200 BC (Bittel 1983). The great empires of the second millennium BC were replaced with a mosaic of small states in the wake of these events. In short, there is considerable evidence for cultural change.

The south-eastern fan appears to become more densely settled in the first millennium BC and it is possible that a palaeochannel connecting the Hellenistic settlements at Kervan Höyük and Kocatömek may date to this period. Turkmenkarahöyük is again settled in this period and may be sited on a route crossing the Konya-Eregli basin to the north of Karadag en-route to Konya, 50 km. to the northwest (Samih Höyük may have had a similar role during the Early Bronze I and II period).

The large second millennium BC city mounds at Alibeyhoyugu, Samih Höyük and Kerhane Höyük become abandoned by the Iron Age. There is a prominent void in the central fan, perhaps an artifact of the burial of Iron Age settlement remains by later alluvial sediment, or indication that locations close to the river in this part of the fan were not suitable for settlement in the period. Continuing work on an early-late division between Iron Age settlements on ceramic typological grounds raises the prospect of additional dating precision in this period.

A second area of low density settlement centres on the sand plain area at the eastern end of the palaeoshoreline spit. The low settlement density in this area may relate to

the relatively poor agricultural potential of the sandplain soils. The natural ford at Seyithan where the Çarşamba breaches the paleoshoreline spit, providing a firm bed of sand and gravel, appears unoccupied during the Iron Age. This is an interesting feature of the Iron Age settlement distribution, as Seyithan seems to be a location of some significance in other periods as a strategic river crossing on the Çarşamba.

Settlements begin to appear away from traditional settlement mounds from the Iron Age onwards, as for example at Kopruxeri, Kizil Hüyük III and surrounding the multi-phase mound at Dedeli Hüyük. The extensive surface scatters of Iron Age ceramics at sites such as Kopruxeri indicate that significant alluvial deposits have not been laid down in this area of the fan in the interval since at least the mid-first millennium BC. The bajada area to the south of the fan again appears to be an important area for settlement in this period, as evidenced by the large settlement at Saksagsan.

The Iron Age and Hellenistic periods see an extension of settlement activity into the south-eastern fan. Kernel density estimates derived from the Iron Age and Hellenistic settlement data show a cluster of new settlements east of the sandplain at the eastern end of the paleoshoreline ridge. From the reconstructed settlement data it appears that conditions in the south-eastern fan were more conducive to settlement during the first millennium BC than in other periods. The pattern of intensified Hellenistic occupation in the eastern fan can be contrasted with the more intensive settlement of the central fan and of the bajadas to the south in the Roman and Byzantine period.

The Hellenistic settlement distribution contains some features that were first seen in the Iron Age, including the continued occupation of the eastern fan. A prominent feature in this period is the group of new settlements north and west of the modern village of Ovakavagi. A second feature of the Hellenistic settlement distribution is the regular division of the landscape and close regular packing of settlements. Locations newly settled in the Hellenistic period tend to be associated with locally low-lying areas of the fan (Baird 1997) as for example at Beskilise, and at locations in the eastern fan towards the Hotamis depression, or around Kuslu Golu in the

central fan. The major population centres during the Hellenistic period are Sircali Hüyük, Seyithan Hüyük and Turkmenkarahöyük.

Settlement activity in the Roman and Byzantine period is highly intensive. There is generally evidence of considerable continuity with the earlier Hellenistic period and of increased settlement density. The exception to this general pattern occur in the eastern and south-eastern fan where large areas that were occupied in the Hellenistic period apparently become abandoned during the Roman and Byzantine period. By the Roman and Byzantine period, some former Hellenistic sites have developed into larger settlements, circa 12-18 hectares, and there is evidence for a major centre at Sayali c. 45 hectares (Baird 1996, Baird 1997). Sayali might have had around 2,000 inhabitants based on a population density of around 40 persons/hectare. Settlement activity is concentrated in the central area of the fan during the Roman and Byzantine period. Baird notes that settlements expand onto the flat plain away from tell mounds in this period, and suggests that this change may reflect developments in land management related to irrigation and land drainage (Baird 1997: 13). An alternative or parallel interpretation might be that variations in the hydrological regime of the fan may have been accompanied by a lowering of groundwater levels. Roman and Byzantine period burials and footings of structures are found at depths below recent historical groundwater levels.

The bajada area south of the fan in the vicinity of Okçu village sees intensified occupation in the Roman and Byzantine period. The available evidence suggests a pattern of increasing aridity during the Roman and Byzantine period with the more intensive occupation of the central fan and the appearance of new settlements in the bajada areas to the south of the basin at the lower ends of gully systems draining upland areas to the south. The trend towards increased dryness may be restricted to the later part of this period, i.e. after *circa* 400 AD when conditions of increased aridity are indicated in both the Van varve record and in the palynological reconstructions from sites in south-western Anatolia (chapter 3).

# Appendix I: List of locations mentioned in text

Name	ID	Easting	Northing	EP	Neo	EC	LC	EB	EB3	2M	IA	HE	RB
"Sircali"	10	477296	4158424							1	1	1	1
"Mezarlik Cumra"	11	479244	4157790					1				1	1
"Kartaltomegi III"	12	478463	4160187					1					
"Karamantomegi"	13	481157	4155312					1					
"Domuzbogazliyan"	15	476935	4176945					1		1		1	1
"Agadami (mvk)"	16	487300	4171012										1
"Tekke Huyuk"	18	479788	4173093					1			1	1	1
"Karatas Huyuk"	19	479305	4168997					1			1		
"Dedeli Huyuk"	20	482132	4165961		1	1		1			1	1	1
"Irmik Huyuk"	21	480604	4162513			1	1	1			1	1	1
"Alemdar"	22	481083	4161257				1	1					
"Musalar"	23	482570	4161689			1		1				1	1
"Okcu Huyuk II"	24	483807	4157626					1				1	1
"Okcu Huyuk I"	25	483975	4155679				1	1					
"Kervan Huyuk"	26	487925	4158328									1	
"Tutuntomegi"	27	485811	4160964									1	1
"Kartaltomegi I"	28	486908	4161354					1		1	1		1
"Seyithan"	29	484949	4162869	1				1				1	1
"Sircak Huyuk"	30	485022	4167020										1
"Catalhoyuk West"	31	484369	4168942			1							
"Catalhoyuk East"	32	484822	4168960		1							1	1
"Kapidalli Huyuk"	33	483802	4170913								1	1	
"Salur Huyuk"	34	484269	4173051				1	1					1
"Avrathani Huyuk"	35	481586	4174022					1					1
"Karaca Huyuk I"	36	482252	4175800					1			1	1	1
"Kizlar Huyuk"	37	485488	4176009					1					1
"Kerhane Huyuk"	38	489096	4176419					1		1			
"Kizil Huyuk I"	39	487907	4172716	1	1	1		1					1
"Kizil Huyuk III"	40	488722	4172988								1	1	1
"Mezarlik II (Karkin)"	41	489236	4171167			1		1					
"Mezarlik Hu. (Karkin)"	42	489996	4170550					1					
"Urumdu Huyuk"	43	487856	4167387				1	1				1	
"Kopruxeri"	44	489851	4166952								1		
"Kizil Huyuk II"	45	490300	4166191								1	1	
"Araboglu"	46	491304	4165740				1	1			1	1	
"Torundede"	47	488596	4164774									1	1
"Kartaltomegi II"	49	488299	4161310					1					
"Boyalitomek"	50	489931	4160744					1			1		
"Kocatomek (I,II,III)"	51	490223	4157888									1	1
"Sarлак Huyuk I"	52	493615	4161636			1	1	1				1	
"Sarлак Huyuk II"	53	493830	4161882				1						
"Mezarlik I (Uchuyuk)"	56	496714	4157430									1	1
"Kuru Huyuk"	57	496824	4159300					1			1		
"Kanli Huyuk"	58	498658	4162203								1	1	
"Alanli Huyuk"	59	498169	4165281								1	1	
"Tastomek"	60	496219	4166444		1	1	1	1					
"Kinikci Huyuk"	61	496008	4168153							1	1		
"Kuslu Huyuk I"	62	493897	4168006								1	1	
"Kuslu Huyuk II"	63	493527	4168219			1	1						
"Bostantomek"	64	493935	4169112								1		
"Halac Huyuk"	65	492796	4169528				1				1	1	1
"Beskilise I"	66	493668	4171902								1	1	1



# Appendix I: List of locations mentioned in text

"Dolay Huyugu"	67	492418	4173172					1	
"Karaca Huyuk II"	68	490659	4175997					1	1
"Cingene Huyuk"	69	492772	4175845		1			1	1
"Pirsanli Hu. (Musalla)"	70	497452	4169220		1				
"Cinili"	72	497864	4172496		1				
"Koseli Huyuk"	73	497541	4175814		1			1	1
"Cumra East"	78	478944	4155756		1				
"Cumra Mezarlik"	79	477122	4156937		1				
"Emirler Huyuk"	83	503435	4170111		1				
"Hu. N of Cumra C"	85	479497	4159398						1
"Kucukkoy"	89	485238	4171465		1				
"Kucukkoy Baraka"	90	486044	4171976		1				
"Samik Huyuk"	91	499996	4172999		1	1	1		
"Turkmenkarahoyuk I"	94	502625	4163714					1	1
"Turkmenkarahoyuk S."	95	501681	4162612		1				
"Sancak Tomek"	100	486817	4166399		1				
"Hayraoglu"	103	488053	4178383						1
"Deliali"	107	478328	4173675		1				
"Kerpik Huyuk"	108	499545	4160415					1	1
"Orta Huyuk"	109	484700	4153700					1	1
"Bozlan Huyuk"	110	495850	4164150		1	1			
"Tolly Tomek"	111	478900	4163000					1	
"Sayali"	112	481900	4152500						1
"Gafuragil"	113	487000	4154050						1
"Turkmenkarahoyuk II,III"	114	502900	4164650						1
"Uchuyukler Mezarlik II"	115	495850	4158275						1
"Kerimin Adasi"	116	480717	4174400		1				
"Musluk"	117	501241	4164247		1				
"Ali Huyuk Tepe"	118	502007	4158396		1				
"Uchuyukler Mez. East"	119	497600	4158000			1	1		
"?"	120	497000	4160800						1
"Kirim Kuyu"	121	483050	4171925						1
"Carsamba Orta"	122	484100	4167000						1
"Akanhan mvk"	123	475165	4163885						1
"Acikuyu"	124	497750	4160325						1
"Irmik II"	125	480025	4162750					1	1
"m29c4.16"	126	482300	4163090					1	1
"m29c4.17"	127	482800	4163225					1	1
"Tenekli"	128	471500	4165750		1	1	1	1	1
"Kumoc"	129	470575	4168025						1
"m29d2.9"	130	467425	4169700						1
"Gokgoz"	131	472950	4166675						1
"m29d2.5"	132	468900	4166075						1
"m29d2.6"	133	468675	4166450						1
"m29d2.7"	134	468550	4166900						1
"m29d2.8"	135	468500	4167025						1
"Godeler"	136	489400	4172150		1				
"Alibeyhuyugu"	137	470450	4154475		1	1	1		1
"Kopruxeri II"	138	489611	4166705					1	
"Yaman Huyuk"	139	464697	4157294					1	
"Abas Huyuk"	140	464137	4155959						1
"m29c4.27"	141	481041	4160032						1
"Kesikler Yayla"	142	497900	4166960						1



Appendix I: List of locations mentioned in text

"Mezgitli"	143	475744	4160353							1	1	1	
"Mahsen Huyuk"	144	495518	4168330	1	1								
"m29c2.33"	145	493006	4166742									1	
"Sakalar T"	146	473950	4159875			1					1	1	
"Sakalar III"	147	473807	4159455									1	
"m29c1.32"	148	488077	4174680			1				1	1	1	
"Cukurkoy"	149	469408	4161706								1		
"Yavsan"	150	466742	4159402			1					1	1	
"Saksagsan"	151	463618	4162410					1		1	1	1	
"Dirabey Huyuk"	152	462525	4165140	1	1					1		1	
"Dana Huyuk"	153	472725	4161700								1	1	
"Cariklar Huyuk"	154	460950	4167540			1	1	1	1	1	1	1	
"Kerpik Huyuk"	155	475275	4156300	1	1	1					1	1	
"Sarnic Huyuk"	156	463050	4168425								1	1	
Total				2	5	16	17	48	6	14	32	50	64

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