Prehistoric vegetation change and woodland management in central Anatolia: late Pleistocene-mid Holocene anthracological remains from the Konya Plain

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ABSTRACT

This thesis presents the results of the analysis of the anthracological remains (charred fuel wood waste debris) retrieved from the archaeological sites of Pınarbaşı, Boncuklu, Can Hasan III, Çatalhöyük East and Çatalhöyük West, located in the Konya plain of south-central Anatolia, Turkey. Together, these sites span the time period between ~15-7.5 ka cal. BP. The main aims of the present study are: (a) to characterise the use of prehistoric woodlands in south-central Anatolia and its changes through time during this critical period for the development of settled life and early agricultural economies, (b) to investigate the nature and scale of woodland management activities and anthropogenic impacts on prehistoric woodland vegetation, and (c) to assess the representativeness of the anthracological assemblages for reconstructing the composition, structure, form and distribution of late Pleistocene and early to mid-Holocene woodland vegetation in south-central Anatolia, and its changing ecologies in relation to climate, woodland growth conditions and human impacts.

Anthracological analyses focused on charcoal macro-remains retrieved from a range of primary (fire features) and secondary (middens, building infill, and general dispersed contexts) fuel wood waste deposits. The methodologies applied included the taphonomic assessment of charcoal densities, standard taxon frequency and ubiquity quantitative analyses, and the quantitative and qualitative analysis of wood calibre and the dendroecological features preserved in archaeological charcoal specimens. The results of these analyses were further explored through the application of a range of multivariate quantitative techniques. The same techniques were also used to integrate the results of anthracological analyses with dung fuel seed archaeobotanical and select hunted and herded faunal datasets, in order to evaluate their co-variation, and thus reconstruct the co-evolution of landscape practices and anthropogenic impacts across space and time.

This thesis demonstrates the unique potential of anthracology to provide novel and highly original insights in the palaeoecology and palaeoeconomy of Southwest Asia, particularly with regard to the investigation of vegetation history, the origin and developments of early anthropogenic landscapes and the nature of people-environment interactions during the transition from foraging to farming.

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CHAPTER 1: INTRODUCTION

The object of the present thesis is the analysis of anthracological macro-remains (the charred residues of wood fuel use) retrieved from late Pleistocene and early to mid-Holocene habitation sites in the Konya plain of central Anatolia, Turkey. The study area is located in semi-arid south-central Anatolia, a region that today is invariably described as a treeless steppe with few surviving woodland remnants (Zohary 1973). The sites included in this study are Pınarbaşı (all phases including Epipalaeolithic, aceramic-late Neolithic and Chalcolithic), Boncuklu (aceramic Neolithic), Can Hasan III (aceramic Neolithic), Çatalhöyük East (aceramic-ceramic Neolithic) and Çatalhöyük West (Chalcolithic) spanning the time period between ~15-7.5 ka cal. BP. In south-central Anatolia this timespan witnessed a series of transformative ecological, socio-cultural and economic shifts that framed the appearance of early settled life, and the onset of plant cultivation and animal herding. In addition, a series of abrupt climatic shifts also occurred during this period that led to important changes in the nature and distribution of water and vegetation resources. Thus the anthracological assemblages from these sites provide a unique opportunity to reconstruct vegetation history and its management by prehistoric communities in south-central Anatolia during this period.

A detailed body of research on the local and regional palaeoclimate and palynological archives has highlighted some discrepancies in the timing of climatic shifts and vegetation change (see Roberts 2002, in press, Asouti and Kabukcu 2014 for comprehensive reviews). In the semi-arid, inland regions of Southwest Asia the response of woodland vegetation appears to have lagged significantly behind the rapid climatic amelioration that marked the onset of the Holocene. Previous interpretations had suggested that this delay was due to negative anthropogenic impacts on woodland vegetation by early Neolithic communities, which hindered its establishment and spread through woodcutting, burning and clearance for cultivation (Roberts 2002, Turner et al. 2010; cf. Asouti and Kabukcu 2014). Within this context two key aspects are called into question: (1) the representativeness of pollen sequences obtained from inland Southwest Asia as a reliable source of proxy palaeovegetation data, and (2) the nature, scale and intensity of Neolithic anthropogenic impacts on the landscape. The absence or under-representation in the regional pollen spectra of important components of the native semi-arid woodlands (members of the Rosaceae family such as *Amygdalus* and *Prunus*, *Pistacia*, *Juniperus*, *Celtis*, etc.) has been already highlighted by some authors (cf.

Roberts 2002, Asouti and Kabukcu 2014). Considering also the poor preservation, low spatio-temporal resolution and the general rarity of uninterrupted pollen sequences across inland Southwest Asia, anthracology provides an invaluable complementary source of proxy palaeovegetation evidence that is moreover tied to radiocarbon-dated archaeological stratigraphies (Asouti and Austin 2005). As it will be demonstrated in this thesis, it also provides direct evidence of the manner and intensity of woodland management, and the ecological conditions affecting woodland growth.

A key objective of this thesis is to characterise the use of prehistoric woodlands and its changes through time via the analysis of anthracological macro-remains. In order to reconstruct routine woodland use practices, the focus is placed on the analysis of fuel wood waste, from both primary deposits (domestic and external fire features) and secondary contexts (middens and other dispersed charcoal deposits, '*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999, see also Chapter 4) accumulated over variable lengths of time. The methods employed include the botanical identification of wood charcoal remains, the quantification of individual charcoal taxon frequencies, and the application of qualitative and quantitative dendroecological analyses (including the recording of fungal decay, growth ring width, ring morphology and anatomy, diameter and curvature estimations, wood anatomical indicators of environmental stress and trauma resulting from climatic events, woodcutting, herbivore browsing, etc.). The aim is to reconstruct the species, form and status of the wood used as fuel, and to characterise woodland growth conditions. The overall objective is to understand the relative importance of woodland composition, ecology and structure, and wood properties in prehistoric fuel selection, and to obtain a detailed picture of woodland use and availability in the landscape. Furthermore, charcoal densities across different context types were systematically evaluated in order to assess the impacts of depositional and post-depositional processes on charcoal preservation and sample composition.

The resulting charcoal taxon frequencies and the dendroecological observations datasets were further explored through the application of a range of multivariate statistical techniques, in order to detect temporal and spatial trends in fuel wood selection and use, and potential variation and changes through time in the growth conditions of individual taxa and their management. Multivariate techniques were also applied to the analysis of anthracological datasets alongside dung fuel-derived seed and hunted and herded faunal datasets. The purpose of this was to detect any co-variation and/or temporal patterning in the use of different fuel sources and woodland catchments. Furthermore, the representativeness of anthracological assemblages for reconstructing the late Pleistocene and early to mid-Holocene vegetation catchments of south-central Anatolia is evaluated through the comparison of the anthracological results with the existing palynological and palaeoclimatic archives. Climatic, environmental and anthropogenic impacts on woodland vegetation are evaluated through the systematic recording of the dendroecological features of fuel wood remains.

The key **research questions** addressed by the present thesis are summarised below:

- What are the prevailing determinants of wood fuel selection and use at each site?
- Are there any spatial (site-specific) and/or temporal shifts in fuel wood selection and use?
- Can fuel wood use be characterised as selective or non-selective at each site?
- What is the role of taxon availability, burning properties and status (e.g., as cut wood or deadwood) in determining its value as fuel?
- What is the nature and intensity of use of different woodland habitats? Is there any evidence for woodland management strategies?
- What was the scale of the anthropogenic impacts and woodland vegetation responses?
- What were the growth conditions and ecological properties (composition, form, structure, density and distribution) of the woodlands exploited for fuel?
- Is there any evidence for the integration of wood fuel collection and woodland management activities with other subsistence-related tasks and landscape practices (e.g., cultivation, herding, raw material sourcing)? Can fuel wood collection and use be modelled in the context of other daily/seasonal/annual economic activities?
- What is the contribution of the anthracological record to the reconstruction of regional environmental and vegetation history? How does it compare with, and contribute to, the picture currently available by anthracological archives from other regions in Southwest Asia?

Organisation of the thesis

Chapter 2 includes a concise review of the literature on the modern vegetation ecology, climate, geography and landforms of south-central Anatolia. In addition, this chapter provides a detailed description of the woodland habitats, historic land use and woodland management practices in south-central Anatolia. The available evidence on the vegetation history and palaeoecology of the region is also discussed, in the context of the available global and regional palaeoenvironmental records, and the anthracological archives from other regions of Southwest Asia.

Chapter 3 provides a summary overview of the key research issues relating to the Neolithic transformation in Southwest Asia, with particular emphasis on the archaeological record currently available from central Anatolia for the periods under investigation. The radiometric dates and main categories of archaeological evidence currently available from all sites included in the present study are also presented, with particular emphasis on the subsistence archaeology datasets.

Chapter 4 presents a detailed overview of the key theoretical and methodological developments in the field of anthracology. Charcoal taphonomy, and the general principles guiding sampling, sub-sampling, quantitative and qualitative analysis, and the interpretation of anthracological remains are critically evaluated and discussed. A separate section deals with the key theoretical approaches and associated ethnographic and anthropological evidence relating to the characterisation and interpretation of fuel wood selection and the representativeness of anthracological assemblages for palaeoenvironmental reconstruction. Finally, the methodologies used for reconstructing wood calibre and dendroecological attributes (and their use for assessing woodland growth conditions and management) are described.

Chapter 5 presents in detail the specific methods employed in the present study, including sampling, subsampling, quantification, and statistical analyses (section 5.1). The results of analyses, including taxon frequencies, dendroecological analyses and the outcomes of descriptive and multivariate statistics, are included in sections 5.2-5.6. The results of these analyses are discussed in detail in **Chapter 6**, in relation to the research questions outlined earlier in this introductory chapter. The key findings and conclusions of the present study, its theoretical and methodological implications for the field of anthracology, and suggestions for future research are summarised in **Chapter 7**.

CHAPTER 2: GEOGRAPHY, CLIMATE, VEGETATION ECOLOGY AND PALAEOENVIRONMENTS

The deep antiquity of continuous human settlement in Anatolia has resulted in a uniquely sculpted environment that reveals the complexity of people-landscape interactions. Plant and animal diversity in the region reflect the transitional location of the landmass bridging two continents, Asia and Europe, and covering three major biogeographic zones: Mediterranean, Irano-Turanian and Euro-Siberian. There are over 9000 different species of vascular plants in Turkey with high rates of endemism (~3000 species unique to the region) and the flora is reportedly one of the richest in Southwest Asia (Davis 1965-1988, Zohary 1971, Mayer and Aksoy 1986, Ekim et al. 2000, Avcı 2005, Çolak and Rotherham 2006). The aim of this chapter is to provide an overview of late Quaternary climate change and the prehistoric, historic and modern day influences on the vegetation ecology of the region, with specific emphasis on central Anatolia and the Konya plain. Archaeobotanical evaluations of the Neolithic vegetation, land use and ecological zones in the vicinity of prehistoric settlements tend to rely on the descriptions and classifications derived from botanical studies of the modern vegetation. In effect, the range of species, their key characteristics, and the zonation of vegetation provided in studies of the present-day regional ecologies constrain and enhance our reconstructions of prehistoric vegetation. In order to address issues relating to the prehistoric vegetation ecology of the region, it is also necessary to understand and evaluate the merits of current and historical approaches to the classification and description of the vegetation of central Anatolia. In section 2.1 the geography, climate and vegetation ecology of Anatolia are summarised, with particular emphasis on the flora and vegetation ecology of the region, and how modern floristic descriptions are used in the context of historic and prehistoric vegetation change. In section 2.2 the geography, climate and vegetation ecology of the Konya plain and south-central Anatolia are discussed in greater detail. In section 2.3 a concise account of the history of forestry and woodland management practices in Anatolia is presented. Section 2.4 covers global and regional trends in palaeoclimate in the late Quaternary and accompanying shifts in the regional palaeovegetation.

2.1. Geography, climate and vegetation ecology of central Anatolia

2.1.1 Geography and physical features

Modern day Turkey, bounded by the Black Sea, the Aegean and the Mediterranean, encompasses Anatolia and eastern Thrace, covering over 750,000 km^2 (Bayazıt and Avcı 1997). In general the eastern sections of the country are more mountainous and rugged, while vast plains spread over the central sector (Atalay and Mortan 2007) (see also Fig. 2.1). The bulk of Anatolia lies on the Alpide belt that stretches from Eurasia to the Himalayas, placing the country in one of the most active seismic zones in the world (Bozkurt 2001). As a result the region has evolved with extensive mountain ranges extending in an east-west direction, in addition to two major transform fault lines: the North Anatolian line running parallel to the Black Sea coast and the East Anatolian line reaching from the northeast to north-central Anatolia (Göncüoğlu 2010). Volcanic massifs (e.g., Erciyes and Hasandağ) in central Anatolia were formed as a result of ongoing collisions between the north moving African, Arabian and Indian plates pushing against the Eurasian plate. The North Anatolian (Pontus) mountain range stretches from the easternmost reaches of the Black Sea coast towards Marmara. This chain is interrupted in many parts by tectonic troughs, valleys and basins. The Taurus mountain range, running parallel to the Mediterranean coast in the south, is more rugged and rises from the west to the east until it reaches the Arabian plate with high peaks reaching >3000 m a.s.l. (Brinkmann 1976).

The Central Anatolian Plateau (~1000 m a.s.l.) is made up of several basins, some of which contained until recently bodies of fresh or saline water of varying quantities (De Ridder 1965). The Taurus and the North Anatolian mountain ranges surround this high-altitude plateau, largely obstructing the passage of humid weather currents inland. Towards the east, where the Taurus and the North Anatolian mountain ranges converge with the Anti-Taurus, the terrain is more rugged and peaks >5000 m a.s.l. are found (e.g., Mount Ararat) (Atalay and Mortan 2007). The south-eastern sector of Anatolia, situated on the extension of the Arabian platform, has a markedly different topography compared to the coastal and eastern regions. Here the relatively flat plains are dissected by the Euphrates and the Tigris rivers, both originating in eastern Anatolia and discharging into the Arabian Gulf.

As a result of the diverse geography and climatic conditions of Anatolia a marked contrast exists in the prevalent soil types between inland and coastal regions (Oakes 1958, Atalay and Efe 2010). Accordingly, zonal soils that depend on the regional distribution of climate types and vegetation cover for their development are ubiquitous (representing ~85-88% of the soil cover in Anatolia). Well-drained brown forest soils and red-brown podzolic soils are prevalent in the forested areas along the Black Sea coast, both formed as a result of high annual rainfall values (Atalay 1989). Mediterranean red soils (terra rossa) extend throughout the Mediterranean and Aegean coastal regions and the mountainous areas bordering the coast (Atalay 1989). As a result of lower rainfall this soil type is generally richer in metal ions compared to the brown or red-brown podzolic soils, and is prevalent on calcareous or limestone bedrock (Atalay and Mortan 2007). Soil formations in central and southeast Anatolia consist of aridisols with low organic content, which is characteristic of the low annual precipitation values in these areas (Atalay and Efe 2010). Despite increasing concerns with aridification, today these regions are considered to be generally better for cereal farming due to less extensive leaching of the topsoil and, especially in central Anatolia, due to its relatively flat topography, favourable for large-scale farming (Atalay and Mortan 2007).

2.1.2 Climate and rainfall regimes

Three main climate regimes prevail in Anatolia: Mediterranean type semi-arid climate (along the Aegean and southern Turkish coasts), temperate and humid climate in the Black Sea coastal region, and continental semi-arid climate in the inland regions (Deniz et al. 2011) Continentality indices (based on the JC index) are higher towards eastern Anatolia, while oceanity indices (Kerner index) are higher along a narrow strip in the coastal regions (Deniz et al. 2011). Significant parts of central and southeast Anatolia display high aridity according to the De Martonne index (Deniz et al. 2011). Areas along the Black Sea coast receive the highest annual rainfall (reaching up to 2500 mm/p.a.) while along the Aegean, Marmara and the Mediterranean coast annual rainfall can reach up to 2000 mm/p.a. (Atalay 1997, Şensoy et al. 2008). With the exception of west-central Anatolia, humid weather currents rarely penetrate the inland regions (Atalay and Mortan 2007). In other parts of Anatolia, to the east and south-east, rainfall tends to be <1000 mm/p.a. (Şensoy et al. 2008) (see also Fig. 2.2).

The Mediterranean-type climate is characterised by high rainfall during winter, and dry and hot summers. Average annual rainfall in the region is around 700 mm, with coastal regions receiving the highest amount of rainfall. The average annual temperature in the Mediterranean climatic region is around 16°C (January average temperature 6.5°C and July 26.5°C) (Şensoy et al. 2008). In the eastern sector of the Mediterranean coast of Turkey summer extremes of 45°C are frequently observed (Atalay and Mortan 2007). Along the Black Sea coast mean annual rainfall is ~850 mm, while the coastal areas receive most of the rainfall throughout the year (as high as 2200 mm/p.a. in the Rize area). However, closer to the Central Anatolian Plateau (e.g., in cities like Çorum) where inland climatic influences are observed, annual rainfall can be as low as 400 mm.

In contrast to the coastal climatic regimes, climatic conditions in the inland regions are much more arid; there are greater temperature fluctuations between seasons and most of the rainfall is received during spring and late winter (Devlet Meteoroloji İşleri 2011). A great portion of mainland Anatolia is under the influence of continental climatic regimes, with slight variations in the east and south-east (Şensoy et al. 2008, Atalay 1997). In the eastern and central regions mean annual temperatures of ~10°C are the lowest in the country. In eastern Anatolia winter temperature averages can be as low as -4°C and in central Anatolia around -1°C (Devlet Meteoroloji İşleri 2011). In both regions July temperature averages 23°C. In southeast Anatolia January average temperatures are 3.5°C and July 30°C (Şensoy et al. 2008). Mean annual rainfall across central Anatolia (~420 mm) is the lowest in the country; however rainfall distribution across the inland regions varies remarkably. Summer aridity is also of longer duration in central Anatolia compared to the eastern regions. In parts of central Anatolia annual rainfall can be as low as 200 mm during very dry years (Devlet Meteoroloji İşleri 2011). Across the inland regions, the extreme seasonal variation observed in temperatures alongside the low precipitation values exercise a significant impact on the distribution of vegetation types. The sharp contrast in the distribution of annual precipitation values between the coastal and inland regions is also graphically demonstrated in Fig. 2.2.

2.1.3 Flora and vegetation ecology

2.1.3.1 Brief overview of the history of research on Anatolian vegetation and flora

Three major phytogeographic studies (Davis 1965-1988, Zohary 1973, Mayer and Aksoy 1986) and a major phytosociological study (Akman 1995) provide a detailed coverage for the whole of Anatolia. Other sources of information either cover single regions (e.g., Walter 1956, Uslu 1959, Quézel 1976, Çetik 1985, Kaya et al. 2009) or focus on individual species and genera (e.g., Birand 1960, Hamzaoğlu and Aksoy 2009, Atalay and Efe 2012, Uğurlu et al. 2012, Uslu and Bakış 2012). Phytogeography – the field of biogeography that is specifically concerned with species distribution, spread, and evolution of plants across the world – has had a strong foothold in botanical research in Turkey. Some of the most comprehensive analyses of the vegetation of Anatolia have come from scholars documenting and defining plant taxonomy in this region, and investigating species distribution and floristic composition of vegetation across Southwest Asia and the Mediterranean (e.g. *Flora Orientalis*: Boissier 1867-1884; *Flora of Syria, Palestine, and Sinai*: Post 1896; *Flora of Turkey and the East Aegean Islands*: Davis 1965-1988; *Geobotanical Foundations of the Middle East*: Zohary 1973).

In his studies of the flora of Southwest Asia, Boissier classified plant distributions within Anatolia into three main zones, based mainly on climatic differences: Mediterranean (*Régions Méditerranéen*, covering the Mediterranean and Aegean coastal areas and adjacent mountainous zones), middle European (*de l'Europe Moyenne*, covering the Black Sea coastal areas and adjacent mountainous zones), and Oriental (*Orientale proprement dite*, covering the inland Anatolian plateaus) (1867: iv-vi). Later Eig (1931) and Braun-Blanquet (1932), building on the work of Boissier, followed a similar vegetation zonation and postulated that the transitional zones within these regions needed further study in order to clearly define regional boundaries. Building on Boissier's *Flora Orientalis*, the *Flora of Turkey* by Davis expanded the documentation of species diversity and distribution across Anatolia. Similarly, Davis separated Anatolian flora in three zones: Mediterranean, Euro-Siberian and Irano-Turanian (coinciding with Boissier's Mediterranean, middle European and Oriental respectively) (Davis 1965: 25-31).

More recent studies of the regional flora by Zohary (1973) and Takhtajan (1986) agreed to some extent with earlier analyses of the Mediterranean and Euro-Siberian regions. Across Southwest Asia Zohary defined five major bioclimatic regions: Euro-Siberian, Mediterranean, Irano-Turanian, Saharo-Arabian and Sudanian (see also Fig. 2.3). Of these, the first three are found in Anatolia, an observation shared by other phytogeographic studies in Anatolia as well (Davis 1965-1988, Mayer and Aksoy 1986). However, disagreements also exist concerning the classification and delimitation of the central Anatolian flora and vegetation. Zohary (1973) classified only the eastern parts of the Anatolian plateau as belonging to the Irano-Anatolian sector of the greater Irano-Turanian region encompassing the eastern Anatolian and Iranian highland plateaux and foothills and the Central Asian steppe. He considered the steppe-forest arboreal vegetation component of central Anatolia (typified by taxa such as *Quercus pubescens* and *Pinus nigra*; see also discussion in next section) as Xero-Euxinian in origin while the ground flora as Irano-Turanian in origin. He moreover classified the outer steppe-forest belt as a sub-class of the Mediterranean bioclimatic region, while he separated an inner “treeless” core as Irano-Anatolian “true” steppe (Zohary 1973: 90, 110, 124, 156, 174-181). By contrast, Davis considers the steppe-forest belt as representative of the transition from the Mediterranean to the Irano-Turanian bioclimatic regions, and treats the *Pinus nigra* and *Quercus* (deciduous) steppe-forests as part of the wider Irano-Turanian region (Davis 1971). This debate (still unresolved) reflects the complexity of modern, historical and prehistoric vegetation dynamics in the wider Anatolian region.

Phytosociological investigations of the flora of Anatolia have placed more emphasis on defining floristic associations of different plant species in a given zone. In phytogeography the species considered as unique to a specific climate type and geographical area (i.e., endemics) are considered to be characteristic of particular vegetation zones. The importance of the actual abundance of such taxa for characterizing a certain vegetation zone may vary (Zohary 1973: 78). In phytosociology, however, data on species presence/absence and abundance in the landscape are systematically collected from random plots and subsequently analysed using multivariate techniques in order to evaluate significant co-occurrences and formal associations of species groups (Braun-Blanquet 1932). Building on Braun-Blanquet’s earlier work, Akman (1995) defined the bulk of vegetation zones of Anatolia predominantly as variants of the Mediterranean type ecosystems with the exception of the northeastern Black Sea coastal region and northeast Anatolia (around Kars and Erzurum) (Akman 1995: 2-5, 7-16, 244). He based his arguments on the observation that summer aridity and winter precipitation are the defining characteristics of Mediterranean ecosystems. However, duration of summer aridity differs substantially across Anatolia. Under the Köppen climate classification system, the Mediterranean climate is referred to as ‘dry-summer subtropical’ (denoted with Cs) (Kottek et al. 2006). When this index is applied to Anatolia, the Csa and Csb classifications (denoting the extent of the Mediterranean climates) are limited to the Mediterranean and Aegean coastal areas only (Şensoy et al. 2008). Therefore, it seems more appropriate to treat the drier inland regions of Anatolia as a separate bioclimatic regime.

The most definitive phytosociological account of the central Anatolian flora remains Çetik’s (1985) monograph *İç Anadolu’nun Vejetasyonu ve Ekolojisi* (‘The Vegetation and Ecology of Central Anatolia’). Çetik (1985) criticises both Zohary’s and Akman’s schemes (Çetik 1985: 21-35) and disagrees with the underlying justification for the classification of central Anatolian woodlands as either Xero-Euxinian or sub-Mediterranean. The author argues that the abundance of character species, endemics and their relative diversity (e.g., number of different species from each floristic zone) should be taken into account when delimiting the extent of the region. In his examination of the ‘transition’ zones between the inland and the coastal region, supported by numerous field observations, the author demonstrates by abundance and diversity measurements that a majority of the north facing Taurus slopes and the south facing north Anatolian mountain ranges display higher degrees of affinity with the Irano-Turanian region (Çetik 1985: 28-32).

In the present research, the bioclimatic classifications proposed by Davis (1965-1988) and Çetik (1985) are followed. The reasons behind this are twofold: first, the different conditions reflected in the three zones (i.e. Euro-Siberian, Mediterranean and Irano-Turanian) based on observations of the climatic, geophysical and geographic characteristics of Anatolia; second, the differences observed in the prevalent vegetation ecologies and plant community formations, as reported in published phytogeographic and phytosociological research. These features are described in greater detail in the following section.

2.1.3.2 Major Anatolian vegetation zones and their floristic composition

The Euro-Siberian zone extends along the Black Sea coast and is typified by a well-developed forest cover of deciduous and coniferous trees and shrubs (Davis 1965, Zohary 1971). The year-round humid conditions support the richest and densest tree and shrub vegetation found anywhere in Anatolia (Atalay and Mortan 2007: 53). At altitudes >300 - 400 m a.s.l. on the north facing slopes of the North Anatolian Mountains, deciduous forests of beech (*Fagus*), chestnut (*Castanea*), lime (*Tilia*), hornbeam (*Carpinus*), alder (*Alnus*) and maple (*Acer*) prevail. In areas where forest cover has been disturbed and parts of the coastal zone that receive less rainfall, mixed shrub and maquis-like formations of honeysuckle (*Lonicera*), box tree (*Buxus*), yew (*Taxus*), service tree (*Sorbus*), hazel (*Corylus*) and wild prune (*Prunus*) predominate (Çolak and Rotherham 2007). Coniferous high-altitude forests (>1000 m a.s.l.) are dominated by Turkish pine (*Pinus brutia*), fir (*Abies*), spruce (*Picea*), black pine (*Pinus nigra*) and more rarely cedar (*Cedrus libani*). In certain parts of the region, especially in tectonic troughs and on the south-facing (towards inner Anatolia) slopes of the North Anatolian Mountains, rainfall can be as low as 400 mm/p.a.; there, semi-arid formations predominate consisting of strawberry tree (*Arbutus*), pine (*Pinus*), juniper (*Juniperus*), sumac (*Rhus coriaria*) and terebinth (*Pistacia*) (Atalay 2002). Turkish pine (*Pinus brutia*) stands are more commonly found in south-facing valleys (Tatlı 2002). >2000 m a.s.l. alpine grasslands of *Festuca*, *Cerastium*, *Androsace* and *Potentilla* are found. Throughout the region the frequency of deciduous oak (*Quercus*) is low; it occurs mostly on the south-facing slopes of the North Anatolian Mountains bordering the Central Anatolian Plateau (Kaya and Raynal 2001).

The Mediterranean zone extending from the southern coastline of Marmara to the Aegean coastal region and the south Anatolian coast is typified by a cover of summer aridity tolerant trees, shrubs and various herbaceous taxa (Akman 1995, Quézel 1986). <500 m a.s.l. vegetation consists of maquis and garrigue dominated by Kermes oak (*Quercus coccifera*), bay laurel (*Laurus nobilis*), strawberry tree (*Arbutus unedo*, *A. andrachne),* tree heath (*Erica arborea*), myrtle (*Myrtus communis*), pistachios (*Pistacia lentiscus*, *P. terebinthus*) alongside several shrubs and other annual and perennial herbs and forbs (Akman 1995, Atalay and Efe 2010). Where maquis has been damaged by overgrazing and clearance, mixed evergreen and deciduous shrubs such as jasmine

(*Jasminum*), rockrose (*Cistus*) and various members of the Leguminosae family can be abundant. At higher altitudes (up to 1300 m a.s.l.) Turkish pine (*Pinus brutia*) forests, sometimes accompanied by Judas tree (*Cercis siliquastrum*) and ash (*Fraxinus*) may occur (Kayacık and Yaltırık 1971, Çolak and Rotherham 2006).

At elevations 1000-2000 m a.s.l. on the north-facing slopes of the Taurus, coniferous forests of black pine (*Pinus nigra*), cedar (*Cedrus libani*), fir (*Abies cilicica*), and juniper (*Juniperus excelsa*, *J. foetidissima* and *J. oxycedrus*) are prominent (Kayacık and Yaltırık 1971, Atalay and Efe 2012). Some scholars have suggested that where *Pinus nigra* forests have been degraded as a result of human impacts shrubby formations of juniper (*Juniperus communis*, *J. oxycedrus*) may occur, especially on the northern slopes of the Taurus facing central Anatolia (Atalay 1987, 1988). As mentioned earlier, there is some debate as to whether the coniferous forests of the north-facing Taurus slopes and the semi-arid steppe woodlands of the central Anatolian Taurus, anti-Taurus and north Anatolian foothill zone and the Cappadocian volcanic uplands (the steppe-forest belt) should be classified as part of the Irano-Turanian or the Mediterranean or the Euxinian biomes. Steppe forest formations consist of deciduous oak (*Quercus pubescens*, *Q. cerris*, *Q. infectoria*), juniper (*Juniperus excelsa*, *J. foetidissima* and *J. oxycedrus*), black pine (*Pinus nigra*), several members of the Rosaceae and Maloideae families (*Amygdalus*, *Prunus*, *Crataegus*, *Pyrus*), buckthorn (*Rhamnus*), oleaster (*Eleagnus*) and terebinth (*Pistacia*).

The Irano-Turanian zone covering central, eastern and southeast Anatolia is typified by steppe vegetation in low-lying areas and mixed coniferous and deciduous dry forests at higher altitudes (Çetik 1985, Mayer and Aksoy 1986). In general, the flora of the region is divided into elevation classes: the plains steppe, the dry forests (also referred to as steppe forests) and the alpine and sub-alpine steppe. Most of the steppe vegetation on the plains of central and southeast Anatolia has been replaced by agricultural fields or has been severely degraded due to increasing grazing pressures (Çetik 1985). This region is one of the most heavily farmed areas in Turkey, especially important for cereal cultivation (Atalay and Mortan 2007). Portions of the steppe remain as grazing grounds, rangelands, or untouched in remote locations and in these areas the most common steppe elements include several members of the Leguminosae (e.g., *Trigonella*, *Lathyrus*, *Vicia*, *Astragalus*, *Genista*, *Medicago*), grasses (e.g., *Agropyron*, *Hordeum murinum*, *Bromus*, *Festuca*), and members of the Asteraceae family (e.g., *Artemisia*, *Centaurea*) (Davis 1971, Çetik 1985). Steppe forest formations in central Anatolia can be found as low as 1100-1200 m a.s.l. and 2000 m a.s.l. in eastern Anatolia with occasional juniper scrub formations alongside members of the Rosaceae and Maloideae families (e.g., *Amygdalus*, *Pyrus*, *Prunus*, *Rosa* and *Crataegus*). These steppe forests can be dominated by black pine (*Pinus nigra*), juniper (*Juniperus excelsa*, *J. oxycedrus*, *J. foetidissima*), and several species of deciduous oak (*Quercus robur*, *Q. petraea*, *Q. pubescens*, *Q. brantii*, *Q. ithaburensis*) (Çetik 1985). While in eastern and southeast Anatolia *Q. brantii* and *Q. robur* are more common elements of steppe woodlands, in central and west-central Anatolia *Q. pubescens* and *Q. cerris* predominate (Uğurlu and Oldeland 2012).

2.2 Geography, climate and vegetation ecology of south-central Anatolia and the Konya Basin

2.2.1 Geography and physical features

The Central Anatolian Plateau is bounded by the Taurus range to the south and the Sultan Mountains and the Lake District to the west. The elevation of the plateau increases in a west-east direction and north-south direction, ranging from ~800-1600 m a.s.l. The Great Konya Basin is located in the south-central sector of the Central Anatolian Plateau (Fig. 2.4), consisting of four distinctive sub-basins: the Konya plain to the west, the Ereğli-Akgöl plain to the east, and the Karaman and Karapınar plains to the south. The basin floor (~1000 m a.s.l.) is formed by the now dry bed of the late Pleistocene Konya palaeolake (Driessen 1970). It is surrounded to the south, south-east and east by the Taurus Mountains. The isolated volcanic massifs of Karacadağ near Karapınar and Karadağ near Karaman add to its topographic diversity.

The basin floor consists of sediments accumulated during the Tertiary and Quaternary sourced from the surrounding uplands, most of which comprise Palaeozoic and Upper Cretaceous limestone (see also Figures 2.5-2.6). Volcanic rocks from the Tertiary are found on its eastern outskirts, especially in the Karaman and Ereğli areas, and limestone outcrops in the south, in the Çumra area (De Ridder 1965, Bozyiğit and Güngör 2011). The sediments that fill the basin are generally >400 m in depth and consist of clay, marl, sand and gravel, in addition to varying amounts of limestone deposits (De Ridder 1965, De Meester 1970: 14). Near Karapınar, Ereğli and Karaman there are also areas with shifting sand dunes and windblown fixed sand dunes (Kuzucuoğlu et al. 1998). At lower elevations, especially on the northern outskirts of the Karaman plain, the original lakebed marl is exposed. The shorelines of the Konya palaeolake can be observed in the Merdiven and Hotamış areas (Roberts 1983). Several parts of the basin are at present severely affected by aridification, soil salinity and alkalinity as a result of the increasingly dry climate, intensified agricultural activity (i.e., irrigation and mechanized ploughing), and dramatic increases in population densities (Dursun and Acar 2011).

From the southern upland zone (Taurus and anti-Taurus foothills) several streams and rivers enter the basin depositing alluvial sediments in wide fans such as the Çarşamba and May fans near Çumra, the Meram and Sille fans on which the modern city of Konya is built, and the Selerecki fan near Karaman (De Ridder 1965, Bozyiğit and Güngör 2011). Of these rivers, Çarşamba has the largest catchment area (see also Figures 2.6-2.7). The Konya Basin is a closed, internally drained basin; for this reason it contains several karstic sinkholes (e.g., Obruk, Timsa, Akçukuru) (Bozyiğit and Tapur 2009).

2.2.2 Climate and rainfall regimes

As discussed earlier in this chapter the Konya Basin is characterised by a markedly continental climate, giving rise to semi-arid steppe vegetation that has been impacted by millennia of continuous human activities, especially pastoral production (Fırıncıoğlu et al. 2007). Annual rainfall on the plateau ranges from ~270 to 350 mm/p.a. Long-term annual precipitation records (1990-2010) tend to vary between different parts of the basin: Konya (295 mm/p.a.), Çumra (307 mm/p.a.), Karaman (311 mm/p.a.), Karapınar (270 mm/p.a.) and Ereğli (282 mm/p.a.) Most of the annual rainfall is received in winter and early spring, thus rendering rain-fed cultivation (especially during dry years) a risky undertaking. The State Meteorology Directorate reports for the Konya Basin indicate that, despite the continuous year to year lowering of annual precipitation values, the amount of summer rainfall (and the number of rainy days during the summer) have been increasing over the last 20 years (Şen and Başaran 2007, Devlet Meteoroloji İşleri 2011). This situation, coupled with the much lower rainfall received during the winter months, is interpreted by these authors as indicating a shift towards an increasingly arid and continental climate. This climatic trend is further accelerated by an overall increase in average summer temperatures. Mean annual temperatures in the Konya Basin (~11°C) do not vary across its different localities as much as rainfall values (Devlet Meteoroloji İşleri 2011). Maximum temperatures reach 40°C in July while minimum temperatures reach -25°C in January and, occasionally, in November and December as well (Devlet Meteoroloji İşleri 2011). The strong seasonal gradients of rainfall (especially summer aridity) and temperature limit the growth season of plants, thus dictating to a great extent the ecology and distribution of the main vegetation types that are found in the Konya Basin today. The predominance of steppe flora on the plain itself largely reflects its very low annual rainfall that has a severe effect on plant growth; ~150 mm of the average annual precipitation are received during the 220 days out of a year with temperatures >8°C (necessary requirements for successful plant growth). There is a strong orographic gradient in precipitation values, which increase gradually with elevation to reach ~500-650 mm/p.a. near Hadim, Çat and Bozkır on the north-facing Taurus foothills. At Akşehir and Seydişehir near the Anatolian Lake District, on the south-western outskirts of the Konya plain catchment area, mean annual rainfall values can be as high as ~700 mm/p.a. (Çetik 1985: 59, Devlet Meteoroloji İşleri 2011).

2.2.3 Vegetation

2.2.3.1 Coniferous woodlands

Mixed or monospecific coniferous woodlands are found at higher elevations on the north-facing slopes of the Taurus (for a summary map of vegetation-rainfall gradients in the Konya plain see Fig. 2.8). Black pine (*Pinus nigra*) forests are the most common above 1200 m a.s.l. with minimum rainfall of 450 mm/p.a. (Çetik 1985: 151-155, Akman 1995: 142). Observations near Karaman report mixed *Pinus nigra* and *Juniperus excelsa* woodlands (Çetik 1985: 231-7). In some locales with rainfall values >600 mm/p.a. *Cedrus libani* and *Abies cilicica* are also rare elements (generally >1700 m a.s.l.) (Çetik 1985: 155-164). In coniferous woodlands ground flora is often poor with some cushion-forming herbs in overgrazed areas. Occasionally *Quercus cerris*, *Crataegus*, *Amygdalus* and other Rosaceae shrubs are also found in *Pinus nigra* woodlands. In general, such woodlands are associated with cooler temperatures and lower rainfall levels compared to similar Oro-Mediterranean formations.

Woodlands dominated by *Juniperus excelsa* and *J. oxycedrus* are found at elevations 1000-2000 m a.s.l. with minimum rainfall of 400 mm/p.a. on the north-facing slopes of the Taurus (Çetik 1985: 228-230). These sometimes form pure stands with very poor ground flora, especially when they are managed for fuel wood and timber, and are also significantly impacted by caprine grazing. Some mixed stands observed on Geyik Dağları, contain deciduous oaks (*Quercus cerris*, *Q. pubescens*), *Amygdalus* and other Rosaceae shrubs alongside a herbaceous ground cover of *Festuca* and *Phlomis* (Çetik 1985: 212, 227, 228). Similar woodland stands near Karaman contain deciduous oaks, *Festuca*, *Thymus*, *Helianthemum* and *Teucrium*.

2.2.3.2 Quercus steppe woodlands

Woodlands with a significant component of deciduous oaks are generally found at lower elevations compared to coniferous woodlands and thus have a lower minimum rainfall threshold (~350 mm/p.a.) (Çetik 1985: 166-168). *Quercus cerris* and *Q. pubescens* are the most common species found in central Anatolia, occurring mostly in the foothill zone of the Taurus and mid-elevation slopes (>1100 m a.s.l.) Observations from Bozkır indicate that *Q. cerris* and *Q. pubescens* are co-dominant when they form a significant part of the woodland composition alongside *Prunus*, *Crataegus* and *Rhamnus* and include a ground flora of legumes (e.g., *Coronilla*, *Trifolium*, *Vicia*) (Çetik 1985: 211-237). Another stand reported from the foothill zone of the Taurus contained *Q. cerris*, *Q. pubescens* as dominant and include *Juniperus oxycedrus* and a ground cover of *Vicia sativa*, *Lens ervoides* and *Lathyrus*.

2.2.3.3 Rosaceae and Pistacia steppe woodlands

According to published vegetation descriptions, members of the Rosaceae and the Anacardiaceae families (*Pistacia*, *Rhus coriaria*) rarely form dominant components of the regional woodlands. *Amygdalus*, *Crataegus*, *Rosa canina*, *Prunus* (plums and cherries) and *Pyrus* are commonly found in the lowland steppes or in association with *Quercus* and *Quercus*-*Juniperus* woodlands on the foothill zone. Rosaceae-dominated woodlands are very rarely observed in this region, usually as a result of severe anthropogenic activities (including pastoralism and wood cutting). *Amygdalus*-

dominated scrub is reported by Çetik (1985: 249-259) from the environs of Aksaray with *Pistacia terebinthus* as co-dominant, including a diverse shrub cover of various Rosaceae, *Capparis*, *Ephedra* and a ground cover of *Artemisia*, *Nigella*, *Ziziphora*, *Salvia*, *Teucrium*, *Astragalus*, *Bromus*, *Stipa* and *Sideritis*. Another interesting association is reported from Bozdağ consisting of *Ephedra* and *Rhus coriaria* (Çetik, 1985: 257). More recently, Asouti and Kabukcu (2014) reported a managed *Crataegus* mature woodland on the foothill zone of the north-facing slopes of Bozdağ, with an undergrowth of *Amygdalus* topiary and *Astragalus* traganthic shrubs. Mixed Rosaceae scrub (*Prunus*, *Rosa*, Maloideae) abounded on the rocky hills above this area, perhaps indicating that its floristic diversity had been maintained due to its inaccessibility to people and livestock. A similar observation by these authors near Sille in the Meram catchment reports of a formation including small-size trees and shrubs in low densities (*Quercus*, *Amygdalus*, *Pyrus*, *Rosa* and *Crataegus*) surviving as a result of low grazing pressure as indicated by the presence of a dense Poaceae ground flora.

The ecological tolerances and the extent of this woodland type (Rosaceae-*Pistacia* and also occasionally *Celtis*) are very important from an archaeobotanical view as they form an important element of edible fruit and nut gathering resource bases. Currently two of these important taxa, *Pistacia* and *Celtis*, have a rather limited range in central Anatolia. Çetik (1985: 254, 104) stresses that *Pistacia* and also *Celtis* can persist near lakes, riverbanks, streams and sheltered valleys by taking advantage of higher moisture in such microclimates. Asouti and Kabukcu (2014) also report on the presence of *Pistacia* and *Celtis* (alongside other moisture-dependent taxa such as *Ulmus*, *Fraxinus* and *Salicaceae*) on the riverbank and along the cliff faces of the Ihlara. Therefore the limiting factor in the extent of *Pistacia* and *Celtis* in central Anatolia may reflect increasing aridity in the region and/or their exclusion from species-poor, heavily managed and degraded wet woodlands.

2.2.3.4 Riparian woodlands

Riparian woodlands in many parts of Anatolia consist of predominantly managed and in some cases planted species. At present there are no old growth riparian woodlands surviving in central Anatolia, due to their destruction by agricultural activities and expanding urban and rural settlement. As a result, riparian formations are very rarely reported in phytogeographic and phytosociological studies. Furthermore, a majority of the literature on forestry and silviculture deems such managed woodlands as degraded and/or wholly anthropogenic artificial woodland habitats. Therefore there is very little information in the literature concerning their ecologies and tolerances. *Salix* (willow), *Populus* (poplar), *Acer* (maple), *Fraxinus* (ash), *Ulmus* (elm) and *Lonicera* (honeysuckle) have all been reported from river valley woodlands and protected wetlands (Çetik 1985: 104, 293). Such woodlands growing on alluvial soils around water bodies, along rivers and streams, and in humid areas may also contain *Celtis*, *Pistacia* and *Crataegus* (Çetik 1985: 104, Asouti and Kabukcu 2014).

2.2.3.5 Wetlands

Marshes near Konya at Kaşınhanı and Karapınar are reported to contain a diverse wetland flora including *Juncus maritimus*, *Atropis*, *Aleuropus*, *Plantago*, *Limonium*, *Salicornia*, *Salsola*, *Scirpus maritimus*, *Cladium mariscus*, *Schoenus nigricans* and *Phragmites australis* (Çetik 1985: 293). Distinct plant communities have been reported from some locales such as Akşehir Lake; *Phragmites australis* (reed) can dominate entire areas irrespective of salinity or alkalinity levels. Where *Bolboschoenus maritimus* is dominant, it is found together with *Althaea officinalis*, *Teucrium scordium*, *Phragmites australis*, *Polygonum* spp. and *Polypogon* on highly alkaline soils (pH=8). *Eleocharis palustris* occurs in semi-waterlogged conditions alongside *Bolboschoenus maritimus*, *Alisma gramineum* and *Rumex* (Çetik 1985: 298-302). Chenopodiaceae-dominated halophytic communities have been reported from the environs of Tuz Gölü, including *Salsola* spp., *Frankenia hirsuta*, *Limonium iconicum* and *Halocnemum strobilaceum*. With decreasing salinity plant communities are dominated by *Juncus maritimus*, *Polypogon maritimus* and *Hordeum leporinum*, while further away the vegetation turns into *Artemisia santonicum* steppe (Çetik 1985: 281, Hamzaoğlu and Aksoy 2006).

2.2.3.6 Treeless steppe vegetation

Herbaceous and shrub steppe communities are presently found on the Konya plain, the surrounding lowlands, around saline depressions and on sand dunes. While south-central Anatolia and the bulk of the Irano-Turanian region are known to contain a rich and diverse steppe flora, very little evidence for such diversity remains in central Anatolia. A majority of the steppe plains have been converted into agricultural land and pastures. Therefore, the ecology of the steppe, in the few places where such vegetation survives, has been severely degraded. Poaceae (*Bromus*-*Stipa*) grasslands have been heavily impacted by grazing; as a result highly palatable grasses and forbs have been replaced by cushion-thorn species (e.g., *Astragalus*, *Centaurea*) and other unpalatable species (e.g., *Peganum harmala*, members of the *Euphorbiaceae* family) (Kurt et al. 2006, Fırıncıoğlu et al. 2009). Pastoral production has been economically vital for central Anatolia since ancient times; thus the impacts of overgrazing are widespread both in the plains steppe as well as in the ground vegetation of upland woodlands whereby fast-growing, short and prostrate species are dominant (e.g., *Thymus sipyleus*, *Genista albida*, *Festuca valesiaca*, *Bromus japonicus*) (Fırıncıoğlu et al. 2007, 2008, 2009).

Artemisia (wormwood) steppes can be more resilient with regard to grazing pressures compared to grasslands. *Artemisia fragrans* steppe vegetation has been reported near Bozdağ, in association with *Poa bulbosa*, *Bromus*, *Noaea mucronata*, *Stipa*, *Agropyron*, *Cousinia*, *Astragalus*, *Onobrychis* and *Allium stamineum* (Çetik 1985: 344-49). Vegetation on sand dunes and sandy soils may contain *Artemisia scoparia*, *Papaver*, *Bromus*, *Astragalus*, *Agropyron* and *Trigonella*. In some locales around Çumra and Karapınar sandy soils with degraded vegetation are dominated by *Centaurea*, *Phleum*, *Thymus* and *Stipa* (Çetik 1985: 357).

2.2.3.7 Vegetation change and succession

An overwhelming majority of literature on vegetation change and composition regarding Anatolia rely heavily on concepts of ‘climax’ vegetation and ‘succession’ (e.g., Akman 1974, 1995, Çetik 1972, 1985, Mayer and Aksoy 1986, Atalay 2002, Gücel et al. 2008, Atalay and Efe 2012). While some of these hypotheses argue that the ‘original’ woodland cover of Anatolia extended over 60-70% of its total land mass (e.g., Louis 1939, Walter 1956, Atalay 2002), others have also proposed that the ‘climax’ vegetation type likely was coniferous forest (Atalay 2002, Atalay et al. 2014). Such hypotheses on the ‘original’ extent of woodland in Anatolia were based on the observations of Louis (1939) and Walter (1956) who postulated that in prehistoric times (i.e., before ~2ka cal. BC) a great majority of the steppe environments in Anatolia could have supported woodlands. Louis (1939) further supported his hypothesis with observations of scattered trees in the margins of the central Anatolian steppe, and suggested that the original extent of ‘true’ treeless steppe in Anatolia would not have been more than 25% of its total landmass. However, no specification was made regarding the nature of such formations or the potential openness of the vegetation structure. Later Uslu (1959) and Mayer and Aksoy (1986: 32-3) made similar speculations on the limits of the 'treeless' central Anatolian steppe and concluded that anthropogenic impacts must have severely reduced the woodland cover of inner Anatolia. The de facto assumption arising from the observations on the steppe forests was that, without human impact, areas outside the 'true' steppe core would have contained densely wooded environments in the past.

As noted above, various scholars (e.g., Akman 1974, Atalay 2002, Atalay et al. 2014) have proposed that in Oro-Mediterranean areas taxa such as *Cedrus libani* and *Pinus brutia* are the 'climax' species, while on the north-facing slopes of the Taurus they are replaced by *Pinus nigra*. They have also suggested that other taxa associated with *P. nigra* such as *Juniperus*, *Quercus* and members of the Rosaceae-Maloideae families represent "regressive" stages of the original climax vegetation that was negatively impacted by people's activities in the landscape. Both Akman (1974) and Çetik (1972) have proposed that under such a scenario *Pinus nigra* climax woodlands would first regress into mixed *Quercus*-*Pinus* woodlands, and later be replaced by *Quercus*-dominated Rosaceae and *Cistus laurifolius* scrub with treeless steppe vegetation as the last (and largely irreversible) stage of vegetation succession.

Both approaches summarised above rely on the idea of a climatic 'climax' as originally proposed by Clements in the early 20th century (Clements 1936). This theory postulates that the species (or groups of species) best adapted to given climatic conditions will form the dominant community, which will remain in a state of equilibrium under conditions of minimal (or no) anthropogenic vegetation impacts. Alternatives to linear succession models can be found in more recent ecological literature that emphasises the complexity of the conditions and different scenarios leading to vegetation change, and highlights the importance of people-plant interactions in the landscape as agents of multi-directional ecological change (cf. Peterken 1981, 1996, Vera 2000, Rackham 2001, Grove and Rackham 2003). However, very few studies focus on the functional ecologies of woodland vegetation in Southwest Asia (for a recent overview see Asouti and Kabukcu 2014). Whether theories postulating the original presence of supposed pristine 'climax' vegetation communities can provide satisfactory explanations of species presence and of stand density, diversity and structure, is a long-lived debate in vegetation science and ecology (cf. van der Valk 2014). However, one certainty is that such a climatically deterministic view of vegetation zonation and classification is bound to overlook key aspects of the physiological and functional requirements dictating the dispersal, establishment, development and dynamics of various woodland taxa and their associated habitats. Recent fieldwork by Asouti and Kabukcu (2014) in south-central Anatolia has demonstrated that across inland Southwest Asia such mature woodlands predominantly exist as intensively managed and overgrazed woodlands. Furthermore, it should be kept in mind that the concept of a ‘climax’ community, as reflected in modern vegetation descriptions of Anatolia, usually refers to mature, old-growth woodland habitats. The distinctions drawn between ‘climax’ *Pinus nigra* woodland and ‘degraded’ *Quercus-Pinus-Juniperus* woodland place the emphasis squarely on negative anthropogenic impacts. Therefore such a regression more likely represents what Clements (1936) referred to as a dis-climax, rather than a sub-climax. In fact, recent research on biogeographic modelling by Evrendilek et al. (2007) on the basis of detailed climatic (rainfall, temperature, solar radiation, frost days, duration of growth season, aridity, etc.) and soil physiology and chemistry dynamic modelling of functional vegetation attributes, demonstrates that the maximum extent of continuous woodland cover in Anatolia could be placed more realistically around 45% of its total land mass. A great portion of the central Anatolian inland regions would either form steppes or semi-arid open woodlands characterised by <20% tree density. The same authors also predict that the plains steppes of central Anatolia have a much greater potential of open shrub cover (with an estimated >80% fractional shrub cover) (Evrendilek et al. 2007).

2.3 History of forestry, woodland management and land use in Anatolia

2.3.1 Forestry in Anatolia

Agropastoral activity has been important in Anatolia for several millennia. Research on the regional prehistoric and historic economies suggests that rural resources have sustained a growing population throughout this time (cf. Akın 2006, Güloğlu 2010, Bogaard et al. 2013). Yet, there have been very few studies concerning the regional *histories* of land use and traditional woodland management practices. After the proclamation of the Turkish Republic in 1923, and following reforms of the regulation of forestry resources, all unauthorized use of *natural* woodlands became illegal. These new policies limited the use of native coppice woodlands as well as transferring the ownership of privately owned lots and plantations in forest zones to the state. Recently, some private ownership claims of wooded areas have even been taken to the European Court of Human Rights (Ayaz 2010). The situation reflects a radical shift in the way woodlands were perceived and used until the beginning of the 20th century AD (i.e., before the establishment of the Republic) in the context of traditional landscape practices whereby woodlands represented a communally used resource for fuel, domestic timber and animal graze and fodder.

Today in Turkey roughly 26.3 million hectares of land are under cultivation (of which 83% dry-farming) and 21.5 million hectares are forested (Miran 2005, Ormancılık İstatistikleri 2010). To a great extent, the total cover of forested areas in the 19th and early 20th centuries has been somewhat stable (Ardıç 1985). The chief cause of this has been that most of the surviving forested areas in historical times have been confined to rocky and mountainous regions that are unsuitable for farming or inconvenient for overland transportation (White 2008). The earliest historical records from this region, especially accounts of travellers passing through Anatolia, indicate that in general forested areas were much more extensive (İnalcık and Quataert 1994). Strabo in his account of the early historic (1st millennium cal. BC) landscapes of Anatolia states that dense forests covered much of the Taurus and parts of inland Anatolia, especially in mountainous areas (Strabo 2000 translated by A. Pekman). It is noted in several documents that various armies traversing Anatolia, or engaging in battles, used extensive forest fires as a method for weakening their opponents' defences. One such incident is reported from the 13th century AD when whole reaches of forests were burned down between Konya and Karaman by the İlkhans attacking the Seljuks (Dursun 2007). What followed after the successive reigns of the Roman, Byzantine, Seljuk and Ottoman empires were long cycles of deforestation and intensive land use, followed by periods of regeneration.

Throughout the Seljuk and Ottoman reign over Anatolia (11th-19th centuries AD), there was a system of land ownership that designated certain areas of forested land as belonging to the imperial system whereby local inhabitants were allowed access to, and use of, the forest resources but were not allowed to claim ownership of them or the land in which they stood (Coşgel 2004). The rest of the land was centrally owned by the local governor and was allocated to households, individuals and communities with the requirement of using it for agricultural production (Öz 2000). As a result, the greater part of the lowland plains and the plateaux were operated under a centrally controlled agropastoral production regime. Historical records indicate that production of cereal grains (wheat, barley and oats) and key traded commodities (e.g., tobacco, hemp, wool, textiles, etc.) comprised much of the agropastoral activity alongside viticulture and livestock herding. Historically, cereal cultivation has been most prominent in the steppe zones of central and southeast Anatolia. The earliest forestry protection agencies were established in the mid-19th century. State agencies deemed forested areas as a collective resource of the society at large and also did not allow for cleared forests to be converted into farming land owned by individuals (Ardıç 1985, Yavuz 2005).

2.3.2 Woodland management

Prior to the establishment of Turkic municipalities in Anatolia in the 11th century AD, the Ağaçeri (literally translating to "tree men") Türkmen, ancestors of the Tahtacı, known for their expertise in woodland management and harvest, had control over the management of the Taurus woodlands (Yalçın 2002). According to some sources, this group practised pastoral nomadism alongside woodland management since the 7th century AD (Yalçın 2002, Büyükokutan 2005, Karaman 2005). Later, under the more centralised rule of the Seljuks and the Ottomans, the Ağaçeri continued their practices and were the principal fuel wood suppliers. We have very little information regarding their precise woodland management practices or preferences for the harvesting and rotation of managed woodlands. After the 17th century, when the Ottomans gained control over a larger portion of Anatolia, some of the Ağaçeri were moved to parts of the Aegean, the Marmara and the Black Sea regions in order to manage woodlands for the purpose of providing timber and lumber, especially for the provisioning of naval construction demands (Dursun 2007). The limited archival evidence indicates that deciduous hardwoods (beech, oak and chestnut) were preferred for charcoal making whereas conifers (pine, fir, spruce, and juniper) were preferred as timber. Trees from either hardwoods or softwoods were used for shipbuilding as long as they were of a specific height, and thus required the management and protection of well-developed, mature forests that were reserved for naval construction (Ardıç 1985, Dursun 2007). The Tahtaci still inhabit several mountainous regions across Anatolia, and comprise an important portion of the state forestry service's workforce (Daşdemir and Kanburoğlu 2009).

Other than the sources discussed above relating to the history of the Tahtacı Türkmen there is hardly any mention of traditional woodland management strategies in historic documentation, ethnographic accounts or silviculture research in Anatolia. Çolak and Rotherham (2006) make a fleeting comment regarding the nature of traditional coppice management systems in Anatolia, which are generally described as simple coppices (unlike the European coppice woodlands with standards). Recently Asouti and Kabukcu (2014) have documented a variety of woodland management practices in several locations around the Konya plain and in west Cappadocia including simple coppicing, pollarding, shredding, and the use of wooded areas as wood pastures. Their field observations are presently the only source of information documenting the ecological signatures of woodland management practices in this part of Anatolia, which contains the majority of surviving native semi-arid woodlands on the Central Anatolian Plateau. These authors have concluded that the variability observed in woodland composition and structure (i.e., stem calibre, crown size, stand density and diversity, growth forms, etc.) depends more on the management techniques employed and the intensity of grazing pressures, rather than on net rainfall values and the availability or particular soil types. Intensively managed deciduous oak woodlands (old-growth coppices and pollards) also used as wood pastures contain even-aged, mature trees (stem diameter >40 cm) recruited in almost exclusively monospecific stands. Due to heavy grazing pressures they contain a very poor ground cover comprising mostly forbs and spiny plants with very low (to nil) seedling and sapling establishment. Lower grazing pressures and less intensive woodland management result in highly diverse woodland communities (often dominated by Rosaceae) that are characterised by low stand density and shorter individuals of much smaller diameter; the ground flora is also rich in annual and perennial grasses and forbs (Asouti and Kabukcu 2014). Similar observations were made by Salehi et al. (2010, 2013) on deciduous oak woodlands in Iran. These authors observed that the largest stem diameter classes are found in the most intensively managed woodlands, which provide fuel wood, leafy fodder and pasture. In such areas, rates of seedling establishment are low to nil, and taxonomic diversity of the arboreal flora is also very limited. Wooded areas located further away from the settlement, where grazing pressures are much lower, are floristically much more diverse and include individuals of much smaller size and variable growth forms (Salehi et al. 2010, 2013). The same authors have suggested that due to the good regeneration properties of deciduous oak in particular, this taxon lends itself to low-level management (i.e., simple coppicing) and this might be the main reason why it is so often preferentially selected in sylvo-agro-pastoral subsistence systems (Salehi et al. 2010).

Information on traditional and historical woodland management practices is far more widely available in European forestry research (e.g., Peterken 1981, 1996, Rackham 2001). Coppicing involves cutting down of tree stands, which re-grow from shoots sprouting from the cut stumps. This is generally carried out on rotation cycles of 5-25 years in accordance with the desired size of logs and the growth rate of the species involved (Peterken 1981: 18-30). Cutting down of coppice stands generally does not include all trees in a given stand; the proportion of individual trees cut and the preferences of the rotation depend very much on economic preferences and the intended use of the harvested poles. In European traditional woodland management, coppice stands are often kept so that a small number of trees reach much larger diameters, often harvested for timber or debarked for use in tanning (Peterken 1981, Grove and Rackham 2003). These larger trees, also called standards, are not commonly observed in Southwest Asia (cf. Salehi et al. 2010, Asouti and Kabukcu 2014). After cutting, the coppiced woodland area would have to be protected from grazing herds for a period of 4-10 years, depending on the speed of growth of new shoots (Peterken 1981: 18-30). When coppice stools are cut close to the ground, this generates a ground level or subterranean stool; however if it is desired to create a higher stool, thus placing the new shoots above the reach of herbivores, then trees can be cut ~1m above the ground level which results in the creation of a pollard (Peterken 1981, Rackham 2001).

It is important to note here that regardless of the method of woodland management (simple coppicing, coppicing with standards or pollarding) regeneration of the woodland from seed is not important, as long as the woodlands remain under a particular management regime. Continuous management ensures that woodland stands can be maintained and renewed for centuries without any natural regeneration, by taking advantage of the ability of established rootstock to regenerate vegetatively. This means that the impacts on the process of natural regeneration of seasonal or interannual variations in environmental variables (e.g., spring frost inhibiting pollination and/or killing-off seedlings and saplings, drought during the growth season, etc.) are also minimised (Peterken 1981: 12).

2.3.3 Agropastoral uses of the landscape

In the last 50 years the amount of land under cultivation in Anatolia has almost doubled (from 14.8 to 26.3 million ha) and the percentage of the population who live in rural areas has more than halved (from 75% to 35%). Coupled with severe population hikes during the same time period, the country has experienced a shift in agricultural strategies towards more intensified and industrial farming whereas most of the areas newly open to cultivation have been in regions where the landscape is relatively flat and close to water sources.

Historical records from the 16th century AD onwards indicate that cereal farming productivity in many parts of Anatolia did not exceed 1:3-4, comparable to traditional methods of dry farming (Öz 1999). Even by the 1950s non-mechanized dry farming was not very common in many parts of Anatolia due to the unsuitability of the soil types and the uneven terrain (Stirling 1965, Erinç and Tunçdilek 1952). The scratch-plough has been, and perhaps remains, the most suitable method of soil preparation in many parts of central Anatolia due to the fact that it does not turn soil over and induce heavy moisture loss by deep cutting. Dung has been used historically for supplementing domestic fuel needs and construction; therefore the use of manure as fertiliser has been rather limited. As a result surplus production in central and eastern Anatolia has never been significantly high (Öz 2000, Tarım ve Köy Işleri Bakanlığı 2004). Instead, the increasing populations in these regions have relied heavily on a variety of economic strategies including animal husbandry, use of wild resources and diverse trade links with neighbouring regions. At times of environmental and political stress, whereby yields from agricultural production have been threatened, communities in these areas have reverted back to pastoral nomadism when necessary (Yavuz 2005). It is noted in historical literature that at times of recurrent annual droughts in parts of central Anatolia communities experienced severe famine and diminished population (e.g., during the Little Ice Age; cf. White 2008). On the other hand, with increasing pressures from the state, especially during the 18th and 19th centuries, farmers in marginal areas (i.e., the dry farming zones of inland Anatolia) cleared patches of forested areas for cultivation in order to be able to pay taxes owed (Dursun 2007).

2.4 Palaeovegetation and palaeoclimate

The period from the end of the Last Glacial Maximum to the mid-Holocene (~20-5 ka cal. BP, often referred to as the late Quaternary period) corresponds to the end of the last Ice Age, the domestication of plants and animals and the establishment of the first distinctly anthropogenic landscapes and agroecologies, and the earliest settled communities across Southwest Asia. This time period is integral to our understanding of the complex history of people-environment interactions, not only because it represents a shift in human perceptions of, and relationship with, the environment but also because it coincided with major changes in terrestrial environments, in particular vegetation ecology, in the region as a whole. Certain climatic shifts observed in Southwest Asia in the late Quaternary reflect to some extent global climatic events and therefore a brief overview of these trends is covered in section 2.4.1 alongside a more detailed account of palaeoclimatic (section 2.4.2) and palaeovegetation (section 2.4.3) shifts observed in Southwest Asia. These are followed by a review of the evidence available from south-central Anatolia and the Konya Basin (section 2.5).

2.4.1 Global trends in late Quaternary climate change

Long-term climatic reconstructions concerning the Northern hemisphere seek to understand major changes in average temperatures and rainfall mostly based on proxy evidence from deep cores from ice sheets (e.g., NGRIP, GISP, etc.). Research has been focused on the evidence provided through oxygen stable isotope values in foraminifera and in water molecules trapped in ice cores retrieved from the polar regions, resulting in a series of cross-correlated sequences spanning the last 100 ka years.

Earlier research on palaeoclimates, mostly based on terrestrial records, used the terminology proposed by Mangerud et al. (1974) that relied heavily on the correlation of climate change with shifts in vegetation cover observed through palynological analyses. The Pleistocene period was divided into glacial and interglacial phases, based on cold/warm phases as reflected in proxy records. However, as argued by Björck et al. (1998) and later emphasised by several other palaeoclimatologists, this terminology is limited in its ability to account for variability across different regions. It also does not allow adding new phases, which may be necessary as a result of new research findings. In addition, the time lags observed between climatic shifts and vegetation change result in problematic regional chronologies, especially if the terrestrial sequences cannot be dated with precision. Therefore in this chapter the more recent terminology proposed by the Greenland ice core projects (which is also correlated with the marine core records from the North Atlantic Ocean) is adopted (see Table 2.1).

The Greenland Ice Core Project (GRIP), the Greenland Ice Sheet Project Two (GISP2) and the North Greenland Ice Core Project (NGRIP) have provided a strongly correlated and high resolution record of climatic fluctuations affecting the Northern Hemisphere covering the last 100k years (Dansgaard et al. 1993, Björck et al 1998, Taylor et al. 1997, Alley et al. 2000, Anderson et al. 2004). These records correlate also with evidence from marine sediment cores from the North Atlantic Ocean (Boyle and Keigiwn 1987, Bond et al. 1992, Robinson et al. 2005).

The general climatic trend from the end of the Pleistocene (including the Glacial Stadials 1 and 2 and the Glacial Interstadial 1) to the Holocene is an overall warming as indicated through annual temperature reconstructions from the Greenland ice cores and from the sedimentation records in the North Atlantic marine cores (Bond et al. 1993, Alley et al. 2000, Robinson et al. 2006). This shift was the result of the gradual change in the seasonality and distribution of solar energy which caused the continental ice sheets to melt (Broecker and Denton 1989). This process of warming was manifest in the oceanic currents with an influx of glacial meltwater; however the short-term outcomes of these rapid meltwater influxes were two episodes of abrupt cold and arid phases that took place before the onset of the Holocene (see also Table 2.1). The Glacial Stadial 2 (formerly referred to as the Last Glacial) between 21,2-14,7 ka cal. BP, which was followed by the warmer and wetter climatic episode of the Glacial Interstadial 1 (formerly referred to as the Bølling-Allerød) between 14,7-12,65 ka cal. BP; and the Glacial Stadial-1 (formerly Younger Dryas) an abrupt cold and arid fluctuation between 12,65-11,5 ka cal. BP. The onset of the Holocene (11,5 ka cal. BP-present) is reflected across the northern hemisphere as a warming episode characterised by increasing levels of precipitation until ~8 ka cal. BP (Climatic Optimum). These general trends are also detected in various terrestrial records and off-shore marine cores in the Eastern Mediterranean and Southwest Asia (Rosen 2007). Two short and abrupt cold episodes (at 8.2 ka and 4.2 ka cal. BP) are also registered in the GISP2, NGRIP and GRIP sequences (Alley et al. 2000, Johnsen et al. 2001). However, the regional magnitude and duration of these two events are still being questioned, especially with regard to their presumed effects on water resources (cf. Wiersma and Renssen 2006, Asouti 2009). Unlike the GS-1 or GI-1, the impact of the 8.2 ka event is not registered on a global scale; its duration and effects on temperature and precipitation are of a much smaller scale compared to the GS-1 event and can be registered in regional sequences with varying durations and magnitudes (Wiersma and Renssen 2006).

2.4.2 Regional trends in late Quaternary climate change

2.4.2.1 Southwest Asia

The regional Late Quaternary climatic records in Southwest Asia come from a number of marine cores in the Mediterranean and the Red Sea in addition to cores from lakes, fluvial sediments, speleothems, pollen records, molluscs and calcretes. Oxygen stable isotope sequences indicate that there was a degree of regional correlation with the global trends in temperatures and precipitation (Kallel et al. 1997, Ariztegui et al. 2000, Rohling et al. 2002, Schilman et al. 2002). As with the rest of the northern hemisphere climatic conditions shifted from cold and arid to warmer and wetter with the onset of the GI-1. This warming and wetting trend was later interrupted by the abrupt cooling and arid GS-1 oscillation, which is reflected in various terrestrial and marine records (Bottema 1991, Rossignol-Strick 1995, Bar-Matthews et al. 2003, Robinson et al. 2006). One of the most detailed sequences in the region comes from the $\delta^{18}O$ values in the Soreq Cave speleothems in the southern Levant (Bar-Matthews et al. 1997, 1999, Orland et al. 2012). Detailed analyses have demonstrated the abrupt onset of the GS-1 event. The isotopic record from Soreq Cave (Bar-Matthews et al. 1997, Orland et al. 2012) registers positive $\delta^{18}O$ (drier) values during GS-1, with a rapid shift to more negative $\delta^{18}O$ (wetter) values at the onset of the Holocene (more so than today). Interestingly, a recent detailed examination of the Soreq speleothems has produced a sequence of proxy indicators for seasonal variations in precipitation, suggesting that year-to-year variations in rainfall values were much higher at the end of the GI-1 (warmer and wetter) compared to the GS -1 (colder and drier) (Orland et al. 2012: Fig. 5). Subsequently, with the onset of the early Holocene rainfall seasonality resembles the current Mediterranean regime in the eastern Mediterranean region. The identified ‘wettest’ phase in Soreq falls between ~8-7 ka cal. BP. Following this phase the mid-Holocene proxy values indicate drier conditions.

The beginning of the Holocene (~11,5 ka cal. BP) marks a rapid increase in precipitation and temperatures across Southwest Asia (Bar-Matthews et al. 1997, 1999, Roberts et al. 2001, 2008, Wick et al. 2003, Sbaffi et al. 2004, Ziegler et al. 2010, Stevens et al. 2012). The Soreq Cave isotopic records have provided valuable insights on the rapidity and magnitude of the climatic amelioration. Based on these analyses it has been suggested that annual rainfall values during the early Holocene could have been as much as 25% higher than the preceding GS-1 phase (Jones et al. 2007). Sofular cave in northwest Turkey, on the Black Sea coast, shows similar $\delta^{13}C$ when compared to isotopic sequences from terrestrial lacustrine sources and the Soreq Cave, suggesting the presence of a wetter early Holocene climatic regime across Anatolia (Göktürk et al. 2011).

2.4.2.2 The picture from the Anatolian Plateau

The Konya Plain and the greater Central Anatolian Plateau have been intensively investigated for palaeoecological research. Lake cores in the vicinity of the Konya Plain from Pınarbaşı, Süleymanhacı, Eski Acıgöl, Akgöl and several other locations in the former Konya palaeolake have provided evidence for complex and variable palaeoenvironments during the late Pleistocene-Holocene transition. Records in most cases are not continuous and dating has been problematic due to the lack of dateable organic material preserved in these semi-arid environments. Cores from the Konya plain (Pınarbaşı, Süleymanhacı and Akgöl) contain hiatuses in deposition, the duration of which cannot be dated with certainty (Roberts in press, Roberts et al. 1999, 2008). These hiatuses likely represent episodes of low lake levels without sediment accumulation and/or erosion of sediments due to deflation (Kuzucuoğlu et al. 1998, Eastwood et al. 2007). The Pınarbaşı sequence in particular is problematic for another reason as well; Hotamış Gölü was an open shallow lake, receiving mostly run-off from Karadağ and the Pınarbaşı spring, hence its hydrology was not determined by local precipitation and evapo-transpiration rates. For this reason the Hotamış sequence does not reflect directly changes in climate (Leng et al. 1999, Reed et al. 1999).

One pattern that emerges from the study of the sequences obtained through coring at closed pluvial lakes across inland Anatolia such as the Beyşehir, Akşehir and Van basins, is that these lakes reached maximum depths during the GS-2 (~23-17 ka cal. BP). Evidence obtained from the Konya palaeolake suggests that it was ~20 m deep and extended over an area of ~4000 km^2 (Erol 1980, Fontugne et al. 1999, Kuzucuoğlu et al. 1999). High lake levels alongside evidence for riverbed incision from the Kızılırmak valley in north-central Anatolia have been interpreted as the result of lower evapo-transpiration rates coupled with higher inputs of snowfall in annual precipitation (Inoue et al. 1998, Sarıkaya et al. 2008, Doğan 2010). Robinson et al. (2006) and Jones et al. (2007) have proposed that the main cause was lower evapo-transpiration as cold conditions during this period were also associated with low annual precipitation. At the end of this period there was a retreat of localised glaciers across inland Anatolia. Following the GI-1 and through a greater part of the early Holocene, various shallow lakes were dispersed across the Konya Plain. Eski Acıgöl, located in Cappadocia provides a climatic record spanning the time period between ~16 ka BP to the late Holocene. The sequence of climatic proxies from Eski Acıgöl based on diatom analyses and carbon and oxygen stable isotope values are in agreement with the regional climatic and vegetation change trends. During GS-1 Eski Acıgöl records indicate colder and drier climatic conditions (positive $\delta^{18}O$ values); at the onset of the Holocene there was a rapid shift to negative $\delta^{18}O$ values, suggesting that the temperatures rose sharply and along with considerably higher precipitation (Roberts et al. 2001). According to Roberts et al (2008) these values mark the wettest phases in the region, which lasted for nearly three millennia (~12-9 ka cal. BP). However, similar conditions at lake Van were not reached until ~8-7 ka cal. BP (Litt et al. 2009).

During the Holocene, extensive alluvial deposits carried by three main rivers (Çarşamba, May, Selerecki) entering the Konya Plain from the Taurus uplands created fan shaped landforms atop the bed of the former palaeolake (Boyer et al. 2007). The Çarşamba and Selerecki fans were host to the Neolithic habitation sites of Çatalhöyük and Can Hasan III respectively. It is difficult at present to reconstruct with certainty the sedimentary environments associated with the earliest phases of Neolithic habitation in the different parts of the plain. Extensive coring and sampling of exposed sections have produced seemingly contradictory results (cf. Boyer et al. 2006, 2007, Doherty et al. 2007, Doherty 2013). This reflects in part the environmental diversity encountered in different parts of the Konya plain during the early Holocene. Another issue inhibiting drawing definitive conclusions is the time transgressive nature of the sediment deposition, which (alongside the ubiquitous radiometric dating issues) results in stratigraphic correlation across different sampled locations being very problematic

(Karabıyıkoğlu et al. 1999, Roberts et al. 1999, Boyer et al. 2006, 2007). A more detailed discussion of the sedimentary conditions and environments pertaining to each locality and site territory is presented in Chapter 6 in relation to the anthracological results regarding the reconstruction of the prehistoric vegetation catchments.

2.4.3 Changes in palaeovegetation

2.4.3.1 Regional trends

Long-term palaeovegetation reconstructions are based on proxy evidence obtained from the analysis of annually deposited pollen sequences preserved in lake bottoms, marshes and other waterlogged environments. In Southwest Asia pollen analysis is often problematic due to the limited preservation of dateable organic matter (including bulk and off-site plant macrofossils) and the discrepancies in pollen production and dispersal behaviour of several key taxa (especially *Juniperus*, *Amygdalus*, Rosaceae, Maloideae and *Pistacia*). Thus most of the published pollen sequences do not provide an uninterrupted, comprehensive record of arboreal vegetation cover through time. In addition, as a result of the insufficient number of ^{14}C dates for various sequences and regional differences in environmental conditions, which dictate sediment deposition rates, it is often difficult to cross-correlate palynological proxy data on a regional basis (Rossignol-Strick 1995, 1999, Rosen 2007: 49).

Pollen records from the coastal areas of the Mediterranean zone (lakes Ghab and Hula in northwest Syria and northern Israel respectively) indicate that with the onset of the warm and wet GI-1 these littoral regions witnessed a rapid increase in arboreal and grass pollen values (Poaceae) coevally with the retreat of *Artemisia*-Chenopodiaceae steppe. During GS-1, this change in the vegetation composition was reversed, leading to a decline in woodland cover, although arboreal pollen values in the coastal areas were higher than those observed in pollen sequences from inland regions (Wright and Thorpe 2003). With the onset of the Holocene, tree cover in the Levantine pollen sequences, mostly comprising *Quercus* and *Pistacia*, did not reach the maximum levels observed during the GI-1. This has been interpreted by some authors as indicating the presence of anthropogenic impacts on the south Levantine arboreal cover through extensive vegetation burning activities (Roberts 2002, Turner et al. 2010). Vegetation firing aside, a more stable ecological balance between trees and grasses likely prevailed in the Mediterranean region during the early-mid Holocene due to its higher precipitation levels. A quicker (by comparison to inland regions) pace of woodland re-advance was probably further facilitated by the proximity of the littoral areas to late Pleistocene arboreal refugia, which likely contributed to the presence of a more permanent woodland cover throughout this period (Rosen 2007, Turner et al. 2010). Pollen sequences from southwest Anatolia, in the Mediterranean biome, indicate that high-conifer woodlands began to spread (possibly at higher altitudes) in the early Holocene consisting of *Pinus*, *Juniperus*, *Cedrus* and *Abies*, while there is also some indication of the presence of deciduous *Quercus*. It should be noted however, that this interpretation relies on cores from Beyşehir, Karamık and Söğüt (van Zeist et al. 1975; Bottema and Woldring 1984), which are not well dated (see also discussion in Roberts in press).

In inland Southwest Asia, including the territories and areas encompassed within the Irano-Turanian bioclimatic region (especially its Irano-Anatolian sector), arboreal pollen sums remained very low by comparison to NAP (steppe shrub and/or herbaceous pollen) throughout the late Pleistocene (Roberts et al. 1999, Litt et al. 2009, Djamali et al. 2010). The pollen sequences from lakes Urmia and Zeribar in Iran indicate that following the rapid termination of the GS-1 the Artemisia-Chenopodiaceae steppe was quickly replaced by Poaceae-dominated grass steppe. However, AP values remained low until ~4 ka cal. BP (Bottema 1986, El-Moslimany 1987, Djamali et al. 2008; see also Wasylikowa 2005). Similar results have been obtained from Lake Van in eastern Anatolia, which has provided one of the longest sequences in inland Southwest Asia (see also Fig. 2.9) (Litt et al. 2009, Wick et al. 2003) and from Eski Acıgöl in west Cappadocia (Roberts et al. 2001, Woldring and Bottema 2001/2). Roberts (2002) and Turner et al. (2010) have proposed that the delayed expansion of deciduous semi-arid woodlands in inland Southwest Asia was the combined result of climatic conditions, human impacts on the woodland vegetation and controlled grassland fires which favoured the spread of grass steppe and prevented the spread and establishment of deciduous woodlands. In a recent re-assessment of the available palynological and anthracological evidence Asouti and Kabukcu (2014 and references therein) proposed that at the onset of the Holocene climatic amelioration, steppe vegetation in inland Anatolia contained an element of sparsely distributed trees or shrubs, which consisted mostly of non-pollen producing Rosaceous shrubs, and taxa such as deciduous oak and juniper at low densities. They have proposed that the delayed *establishment* and spread of deciduous oak-dominated woodlands was due to the competitive advantage of grasslands over trees in seedling establishment, which resulted in a more pronounced abundance of high biomass-producing grasses in these semi-arid environments. These authors argue that the spread of deciduous woodlands in the inland regions of Southwest Asia was the combined result of climate change in the course of the early Holocene and the landscape practices of early Neolithic settlements. The latter included woodland management practices and the widespread adoption of caprine herding, resulting in the selective thinning of shrubby species and increasing grazing pressures on grasslands, which resulted in the availability of more moisture, soil nutrients and solar radiation to woodland species (ibid.)

2.4.3.2 The picture from central Anatolia

The earliest phase of the palynological sequence obtained from Eski Acıgöl, potentially dates to the end of the GS-1 and correlates with the GS-1 phase at Lake Van showing high values of *Artemisia*-Chenopodiaceae pollen (Fig. 2.10). *Artemisia* steppe was rapidly replaced by grassland vegetation at the onset of the Holocene. For nearly another 2000 years, the Eski Acıgöl pollen sequence registers low levels of deciduous *Quercus*, *Pistacia*, and *Juniperus*. The first AP maximum is not registered until ~8 ka cal. BP (Roberts et al. 2001, Woldring and Bottema 2001/2).

Another pollen sequence covering the period between 13-9 ka cal. BP has derived from Akgöl in the Konya plain (Fig. 2.11) (Bottema and Woldring 1984; see also Turner et al. 2010). This sequence stops abruptly at ~9.5 ka cal. BP due to a hiatus in lake sedimentation as a result of a periodic drying up of the lake and paleosol formation (cf. Eastwood et al. 1999, 2007, Roberts et al. 1999, Charles et al. 2014). Its remaining part reflects late Holocene developments. The early part of the Akgöl sequence confirms the trends observed at Eski Acıgöl and Van: *Artemisia*-Chenopodiaceae steppe prevailed in the Konya region until about 12.5 ka cal. BP, followed by a rapid increase in grass cover. A gradual retreat of grasslands from ~9.5 ka cal. BP is indicated by the reduction of micro-charcoal influx at both the Eski Acıgöl and the Akgöl Adabağ sequences, which has been attributed to the suppression of grass fires due to low fuel loads in the environment (Turner et al. 2010). Woldring and Bottema (2001/2) interpret the grass pollen decline at Eski Acıgöl as the result of increasing aridity due to a concurrent increase in *Artemisia* pollen especially during Phase 4 of the Eski Acıgöl pollen sequence. However, they also note that there is an increase, at the same time, in the values of spiny and unpalatable taxa (*Centaurea*, *Noaea*, *Cirsium* and *Matricaria*). The co-occurrence of *Artemisia*, with these taxa indicates increasing grazing pressure on grassland habitats likely resulting from more extensive pastoral activities in the landscape (Asouti and Kabukcu 2014). Deciduous oak continued its expansion until ~4.5-4 ka cal. BP when significant anthropogenic deforestation can be detected for the first time (cf. Roberts et al. 2001, Woldring and Bottema 2001/2). At lake Van in eastern Anatolia, the onset of large-scale anthropogenic deforestation dates even later at ~2.5k cal. BP (Litt et al. 2009).

2.4.3.3 The regional anthracological record

An additional source of evidence for regional palaeovegetation change is provided by anthracological remains retrieved from stratified archaeological deposits (see also Chapter 4: Anthracology: Taphonomy and Methods). The earliest evidence from the Konya plain comes from the Epipalaeolithic levels at Pınarbaşı; the anthracological assemblage contains a relatively diverse semi-arid woodland component including *Amygdalus*, *Juniperus*, *Celtis,* Maloideae, *Fraxinus* and Salicaceae (Kabukcu and Asouti in Baird et al. 2013). Two other Epipalaeolithic sites, Öküzini and Karain B, also contain a similar anthracological assemblage (Martinoli 2004) comprising *Amygdalus*, *Juniperus* and Maloideae. Previous work on early Holocene anthracological assemblages from sites in the Konya Plain shows that taxa such as *Quercus*, *Juniperus*, *Amygdalus*, *Prunus*, *Pistacia*, *Celtis*, Maloideae, Salicaceae, *Ulmus*, *Fraxinus* and *Tamarix* were present in the regional vegetation (Asouti and Hather 2001, Asouti 2003a, 2005, 2013).

Preliminary reports from Can Hasan III near Karaman (Willcox 1974, 1992) and Aşıklı höyük in west Cappadocia, on the north-eastern edge of the Konya plain (Woldring and Cappers 2001, Woldring and Bottema 2001/2; see also Asouti and Kabukcu 2014: 177) indicate the presence of a similar range of taxa. Anthracological assemblages from early Holocene sites in east and southeast Anatolia and northern Syria (Çayönü, Hallan Çemi, Körtik Tepe, Göbekli Tepe, Cafer höyük, Abu Hureyra, Mureybet, Jerf el-Ahmar) include *Quercus*, *Pistacia*, Salicaceae, *Amygdalus*, Maloideae and *Celtis* (cf. van Zeist and de Roller 1991/2; Willcox 1992, 1999, 2002, Rosenberg et al. 1995, Helmer et al. 1998, Neef 2003, Riehl et al. 2012) (see also Table 2.2). In southwest Syria, anthracological remains from the site of Baaz, corresponding to GS-1 and the early Holocene, indicate the presence of *Amygdalus*-*Pistacia*-Maloideae open woodland alongside riparian Salicaceae (Deckers et al. 2009). At sites in the Iraqi and Iranian Zagros *Pistacia* is ubiquitous in late Pleistocene and early Holocene charcoal assemblages (Karim Shahir, Chogha Golan) while deciduous oak appears only from the 7th millennium cal. BC onwards alongside *Pistacia* and *Amygdalus* (e.g., at Jarmo and other sites further south, in the Fars region) (Asouti pers. comm.). Further south, late Pleistocene to early Holocene anthracological assemblages from the Irano-Turanian zone of the southern Levant (Basta, WF16, Saflulim, Ma'ale Ramon) are also dominated by *Pistacia* and/or *Juniperus* (Baruch and Goring-Morris 1997, Austin 2007, Neef 2004a) with the exception of LPPNB 'Ain Ghazal, which is dominated by deciduous *Quercus* (Neef 2004b) (see also Table 2.3).

2.5 Summary

The present-day vegetation ecology of south-central Anatolia has been shaped by millennia of human activities and climatic fluctuations. The time period discussed covers three abrupt climatic shifts, reflecting initially the retreat of glaciation in the region (GI-1), followed by a cold and dry phase (GS-1) and the climatic amelioration of the onset of the Holocene establishing optimum conditions across Southwest Asia. The effects of various climatic fluctuations did not always translate in abrupt shifts in woodland vegetation form, structure and dispersal especially in central and eastern Anatolia, a situation reminiscent of other inland regions of Southwest Asia. The modern distribution and composition of woodland habitats have been heavily impacted by historical clearance events, increasing agricultural activity and expanding urban settlements in the region. Therefore, the classification of central Anatolian vegetation as 'treeless steppe' and the antiquity of anthropogenic negative vegetation impacts are called into question. Specific woodland types of south-central Anatolia, such as riparian and semi-arid *Quercus* woodlands, were discussed highlighting the significance and potential nature of 'natural' as well as managed woodlands in the fabric of the local vegetation formations. Finally, the consideration of anthracological datasets from various prehistoric sites highlights the potential contribution of macrobotanical remains to a more comprehensive understanding of palaeovegetation change across Southwest Asia resulting from both anthropogenic and climate impacts. In the next chapter the major socio-cultural developments in Southwest Asia and their manifestations in south-central Anatolia are discussed.

CHAPTER 3: THE ARCHAEOLOGICAL CONTEXT

3.1 Overview of the Neolithic transformation in central Anatolia

The timespan covered by the present study, ~13-5.5 ka cal. BC, represents not only a period of transformative environmental and climate change in Southwest Asia, but also a period of significant socio-cultural change. Of all associated developments two are crucial for understanding changing perceptions of the environment and people-environment interactions: the establishment of settled life ("sedentism") and of plant cultivation and animal herding leading to domestication and agriculture (Zeder 2009, Asouti and Fuller 2012, 2013). While these two processes unfolded more or less synchronously, they were not coterminous across Southwest Asia and their 'spread' was not unidirectional. In the most commonly used culture-historical terminology in Southwest Asia, the periods in question are the Epipalaeolithic (~20-9.5 ka cal. BC), the Pre-pottery Neolithic (PPN, ~9.7-7 ka cal. BC), the Pottery Neolithic (~7-6 ka cal. BC) and the Chalcolithic (~6-4 ka cal. BC) (Sagona and Zimansky 2009) (see also Table 3.1, Figures 3.1a-d). This terminology relies heavily on archaeological research in the Levant, which is considered by some scholars to represent a 'core' region for the development of sedentism, agriculture and the Neolithic way of life (Bar-Yosef 1998, Cauvin 2000 cf. Asouti 2006). The most problematic issue when dealing with the speed of socio-cultural transformations in the wider region of Southwest Asia is the difficulty of correlating the various regional chronologies. Often absolute dates do not fully correlate with culture-historically defined periods. The central Anatolian Neolithic forms a typical example of this situation (Baird 2012, Watkins 2008). Therefore, an alternative periodization has been proposed for central Anatolia, suggesting a more neutral terminology (Table 3.2) (Özbaşaran and Buitenhuis 2002).

In very broad terms, across Southwest Asia late Pleistocene populations comprised hunter-gatherer communities, often described under the term Epipalaeolithic and identified predominantly through their lithic industries dominated by microliths of various reduction techniques and types (Sagona and Zimansky 2009, Düring 2010, Maher et al. 2012). Following the onset of the Holocene at ~9.5 ka cal. BC a wide range of cultural and economic practices lasting for approximately two millennia gave way to mixed agro-pastoral economies by ~7.5 ka cal. BC (Asouti and Fuller 2013). The millennia preceding the widespread adoption and spread of domesticated crop cultivars and animals represent the early PPN, sometimes also referred to as the aceramic Neolithic. Both terms allude to the absence of widespread ceramic vessel manufacture and use. One of the key debates in the prehistoric archaeology of Southwest Asia is whether the socio-economic transformations observed across the region during the late Pleistocene-early Holocene transition are better conceptualised as a polycentric phenomenon (Gebel 2004, Kozlowski and Aurenche 2005, Watkins 2008) or as processes radiating from few 'core' areas through demic and/or cultural diffusion and acculturation (cf. Childe 1928, Bar-Yosef 1998, 2002, Cauvin 2000, Bellwood 2005, Asouti 2006, Asouti and Fuller 2013). The exact details of the mechanisms involved are beyond the scope of the present thesis. A brief account of the processes phenomena associated with the Neolithic transformation in central Anatolia is provided below. This is followed by a concise description of the currently available evidence on the settlement structure, the subsistence archaeology datasets and the chronology of the archaeological sites studied in this thesis.

Remarkably few Epipalaeolithic sites have been detected in central Anatolia through survey and excavation (cf. Baird 2002, Erdoğu and Kayacan 2004) (for a map of the prehistoric sites in central Anatolia mentioned in the text see Fig. 3.2). Pınarbaşı (one of the sites included in the present study) is the sole Epipalaeolithic site in central Anatolia which has been excavated and studied in detail (Baird et al. 2013). The site (dated to 14-12 ka cal. BC) is broadly contemporary with the later Epipalaeolithic levels at Karain B and Öküzini near Antalya on the Turkish southern Mediterranean coast (Otte et al. 1995, Yalçınkaya et al. 2002, Kartal 2009: 66), and earlier than Direkli dating to the 11th-10th millennia cal. BC (central Taurus range, on the drainage of the Ceyhan river) (Arbuckle and Erek 2012). The cave sites of Beldibi and Belbaşı near Antalya have been provisionally dated to the 13th-11th millennia cal. BP (Kartal 2009: 56-61; see also Bostancı 1967). The scarcity of Epipalaeolithic sites in the central Anatolian plateau reflects the difficulty in the detection of pre-Holocene sites in surveys, as they are likely to be open air sites and rock-shelters deflated by erosion (Roberts 1991) or lay buried under Neolithic tell sites. A similar problem exists with the identification of smaller aceramic Neolithic sites that may be buried under metres of later alluvial deposits (Baird 2005, Boyer et al. 2006).

The earliest evidence of early Holocene habitation sites in central Anatolia comes from the open-air site of Pınarbaşı (Karaman, 8.7-8 ka cal. BC, Baird 2012a), followed by the more substantial tell sites (höyük) at Aşıklı höyük (levels 5-3) (west Cappadocia, >8.4-8 ka cal. BC, Esin and Harmankaya 1999, Özbaşaran 2012, Stiner et al. 2014) and Boncuklu höyük (Konya plain, ~8.4-7.4 ka cal. BC, Baird et al. 2012). In other parts of Southwest Asia the 10th and early 9th millennia cal. BC witnessed the establishment of the earliest settled communities associated with pre-domestication cultivation and animal herding. At several sites in the southern Levant (e.g., Jericho I, Tell Aswad I), northern Syria (Jerf el Ahmar, Dja'de), southeast Anatolia (Nevali Çori, Çayönü) these developments appear to reflect an increasing reliance on cereals and legumes in the subsistence economy (Asouti and Fuller 2013). However, in central Anatolia, sedentarising communities of this period (e.g., Pınarbaşı) do not appear to have incorporated grain producing plants into their subsistence strategies (Fairbairn et al. 2014). At the same time, they display clear evidence of increasing investment in habitation with partly sunken, wattle and daub structures sometimes associated with burials, hunting large mammals and nut collection and processing (Baird 2012b).

A wealth of information on regional interactions and subsistence dynamics in central Anatolia is available from the later aceramic Neolithic and ceramic Neolithic sites of Can Hasan III (Karaman, 7.6-6.6 ka cal. BC, French et al. 1972), Musular (west Cappadocia, 7.5-6.5 ka cal. BC, Özbaşaran 1999), Suberde (Taurus lake district region, 7.6-6.7 ka cal. BC, Bordaz 1973), Çatalhöyük East (Konya plain, 7.3-6 ka cal. BC, Hodder 2014a) and Erbaba (Taurus lake district region, 6.7-6 ka cal. BC, Bordaz and Alper-Bordaz 1982). The Neolithic of central Anatolia, broadly contemporary with the late PPNB, PPNC and ceramic Neolithic periods of the southern Levant), is typified by agglutinative and densely populated sedentary sites such as Çatalhöyük East and Aşıklı (level 2; dated at ~8-7 ka cal. BC, Esin 1998). At both sites herding and the cultivation of domesticated cereal and pulse crops played a prominent role, though hunting and the gathering of wild fruits and nuts also contributed to the subsistence economy (cf. van Zeist and de Roller 1995, Buitenhuis 1997, Asouti and Fairbairn 2002, Martin et al. 2002, Fairbairn et al. 2002, 2005, 2007, Russell and Martin 2005, Bogaard et al. 2013, Russell et al. 2013). At Can Hasan III, Suberde and Erbaba while plant cultivation and herding are attested, hunting still contributed to the subsistence economy (cf. Payne 1972, Hillman 1978, van Zeist and Buitenhuis 1983, Martin et al. 2002, Arbuckle 2008a-b). Boncuklu on the other hand, is a much smaller site; so far it has provided evidence for what could be termed "low-level food production" based on hunting with low contribution of plant cultivation to local subsistence strategies (Fairbairn pers. comm.) Thus it would seem that local communities continued using their traditional (or historical) ecological practices in order to support more settled lifeways and habitations.

The Neolithic-Chalcolithic transition (~6 ka cal. BC) is evidenced at Çatalhöyük (with the shift of habitation from the east to the west mound; cf. Mellaart 1965), Can Hasan I (French 1998), Tepecik (Bıçakçı et al. 2012) and Koşk höyük (Silistreli 1989, Öztan et al. 2007). This period is characterized by the widespread adoption of painted pottery and the regional proliferation of habitation sites. In south-central Anatolia numerous sites dating to the early Chalcolithic have been detected both in the Konya plain and in the wider region (Baird 2002, 2012a). The available evidence points to gradual changes in habitation and subsistence strategies rather than a radical shift in socio-economic and cultural practices. At Çatalhöyük for instance, changes in architecture, lithic technology and the subsistence economy seem to have been underway already from the later phases of the Neolithic habitation on the east mound; the move to the west mound at the beginning of the early Chalcolithic (~6 ka cal. BC) might be better explained in the context of settlement expansion in the wider region during this period (Marciniak and Czerniak 2007, Biehl et al. 2012).

3.2. Overview of the archaeological sites studied in the present thesis

This section includes concise summaries of the archaeology of the sites whose anthracological assemblages are studied in the present thesis. These accounts are provided here in order to introduce readers to the main features of each site, their chronologies, phasing, key material culture attributes, and their respective subsistence economies. More detailed discussion of specific features and related contextual information that are relevant to the interpretation of the anthracological evidence are provided in Chapters 5 and 6 alongside the presentation, interpretation and discussion of the results of the anthracological analyses.

3.2.1 Pınarbaşı (Watkins 1996, Martin et al. 2002, Asouti 2003a, Baird 2007, Baird et al. 2011, Baird 2012b, Baird et al. 2013, Baysal 2013, Fairbairn et al. 2014)

The multi-period open-air site and the rock shelters of Pınarbaşı are located on the southern edge of the Konya basin, on the foothills of the volcanic massif of Karadağ that form part of the low-lying limestone hills of the Bozdağ range (see also Figures 3.3, 3.4). Pınarbaşı is situated ~25 km south-east of Çatalhöyük and ~30 km south of Boncuklu. To date excavations and have identified four periods of occupation: Epipalaeolithic, 9th millennium cal. BC (aceramic Neolithic), late Neolithic and Chalcolithic.

3.2.1.1 Epipalaeolithic occupation at Pınarbaşı

Epipalaeolithic occupation has been identified in the rock-shelter, in deposits underlying the late Neolithic use of the rock-shelter as a hunting and herding campsite (see also Figures 3.4, 3.5, Table 3.3). Two dates on human bone recovered from burials and three dates on animal bone provided a date range of ~14-12 ka cal. BC. It is likely that the occupation extended earlier and later than this interval, because significant deposits above the dated burials exist. Therefore, the site is likely to have been used through the later GS-2, GI-1 and possibly even as early as the beginning of GS-1. Based on the available dates, the Pınarbaşı Epipalaeolithic occupation may predate and is contemporary with the early-late Natufian periods of the Levant. The lithic assemblage, characterised by lunate microliths, was in use from the earliest parts of the sequence, and signifies a highly curated lithic assemblage likely associated with a mobile group. The toolkit comprises mostly knapped obsidian, most likely obtained from one of the Cappadocian sources. Use wear analysis on microliths suggests that they were used for cutting meat and other soft tissues. Some tools might have been used for hide processing. Based on evidence from archaeobotanical remains and migratory birds, the seasonality and duration of occupation likely spanned the spring and summer seasons, perhaps extending into early autumn. In addition, a large number of *Dentalium* and *Nassarius* shell beads (>180) were recovered from the Epipalaeolithic deposits, a majority of which were found in situ in one of the burial features. These marine shells were obtained from the Mediterranean shores ~200 km south of the site.

Dietary evidence from nitrogen and carbon stable isotopes, zooarchaeological and archaeobotanical remains suggest that hunted animals and wetland animals played an important role, while plant foods made a minor contribution to the subsistence economy. Faunal remains identified on site include *Bos primigeniu*s (aurochsen), *Ovis/Capra* (sheep/goat), and equids. In addition a number of smaller wild animals such as *Canis* (wolf), *Felid* (wild cat), *Vulpes* (fox), *Lepus* (hare) and *Testudo* (tortoise) were also found in addition to numerous small freshwater fish remains. Plant macro-remain and phytolith analyses have provided evidence for the presence of a diverse wetland flora in the vicinity of the site including *Phragmites* and Cyperaceae, which might have been used as matting, bedding and tinder. The rest of the macroremain assemblage suggests the presence of a drier, steppic herbaceous cover including *Festuca*, *Helianthemum*, *Hordeum* (wild-type), and several Boraginaceae. There is very little evidence for the use of wild fruits and nuts, with one fragment of *Pistacia* nutshell present in the flotation samples. Evidence for plant food processing was also very scant, with only one ground stone implement found, which might have also been used for ochre grinding. The wood charcoal evidence forms part of the analysis for the present study and will be discussed in more detail in Chapter 5 and 6. A diverse arboreal flora was detected including *Juniperus*, *Amygdalus*, *Pistacia*, *Celtis*, *Fraxinus* and Salicaceae. Overall, the evidence from Pınarbaşı indicates the local presence of a mobile group focusing on the hunting of larger mammals and aquatic resources (e.g., fish and wetland birds) with links to the wider landscape for resource acquisition (e.g., obsidian) and obtaining decorative items (e.g., marine shells).

3.2.1.2 9th millennium cal. BC occupation at Pınarbaşı

Aceramic Neolithic layers were identified in areas A, C and D (Fig. 3.4) and have been dated to 8.7-8 ka cal. BC (Table 3.4, Fig. 3.6). The aceramic Neolithic habitations consisted of partly sunken, wattle and daub structures. The lithic industry consists primarily of microliths and bladelets made mostly from obsidian and reflects regional ties with other settlements such as Boncuklu (see below, section 3.2.2). Several ground stone implements were found which were likely used for processing meat, nuts and ochre. In addition, ground stone axes/celts (both in finished form and as blanks) on green diabase were found at the site, elements of the toolkit which are similar to the Çatalhöyük repertoire (see below, section 3.2.4). Marine shell beads (*Dentalia*, *Nassarius*) were recovered also in the aceramic Neolithic phase, most likely sourced from the Mediterranean. In addition, a number of stone beads of basalt, limestone and marble were also recovered.

Similar to the Epipalaeolithic occupation, there is no evidence for the use of wild-type cereals or legumes from either the plant macro-remains or the phytolith assemblages. By contrast, *Amygdalus orientalis*/*graeca* and *Pistacia* nutshell and *Celtis tournefortii*/*glabrata* stones were found in abundance. In addition, several seeds of wetland species (e.g., *Cladium mariscus*) and other herbaceous taxa (e.g., *Puccinellia*) were found. Previously reported wood charcoal finds indicate the continued presence of *Amygdalus*, *Pistacia*, alongside the remains of *Artemisia*, Chenopodiaceae, Leguminosae and Maloideae. It seems that similar to the Epipalaeolithic phase, the focus was placed on hunting of mammals (aurochsen and equids), wetland birds and fish. Reportedly, archaeobotanical and zooarchaeological seasonality indicators suggest that the site was occupied during spring, summer, autumn and early winter; however it is not clear whether the site was continuously occupied year-round or if there were intra-annual variations in the duration of occupation.

3.2.1.3 Late Neolithic occupation at Pınarbaşı

The late Neolithic occupation was identified in area B (Figures 3.4, 3.5, 3.7, 3.8) and is dated to 6.5-6 ka cal. BC (Table 3.5). The chipped stone industry of this occupation phase consists mostly of Cappadocian-sourced obsidian; tools are made with similar reduction techniques and consist of tool types similar to those found in the later Neolithic levels of Çatalhöyük. The seasonality evidence based on the zooarchaeological and archaeobotanical datasets (e.g., nut-gathering, the presence of caprine neonates and certain migratory birds in the assemblage) suggests that the site was occupied in the spring, late summer and early autumn. Based on the season of occupation, the lithic evidence and the lack of substantial habitation structures, it has been suggested that the site served as a seasonal camping area for herders and hunters who had ties with Çatalhöyük. Marine shell beads of Mediterranean origin (*Dentalium* and *Nassarius*) are also found in this phase of occupation.

The faunal assemblage is dominated by domesticated caprines (mostly *Ovis* and some *Capra*), while there is also a considerable amount of *Bos primigenius*, equids, *Cervus* (deer) and *Sus* (boar). The isotopic signatures of the caprines from the late Neolithic occupation are very similar to those from the late levels at Çatalhöyük (see section 3.2.4) suggesting a diet comprising of both C3 and C4 plants. Plant foods were rare in the assemblage, with some cereal remains, *Pistacia* and *Amygdalus* nutshell and

Celtis stones. Evidence from phytolith and plant macroremains suggests that reeds and sedges might have been used perhaps for erecting light structures. Previously reported wood charcoal macroremains consist of *Amygdalus*, *Pistacia*, *Tamarix*, *Fraxinus*, *Celtis*, *Artemisia*, *Capparis*, *Rhamnus*, *Juniperus*, Leguminosae and (very rare) *Quercus* and *Acer*.

3.2.1.4 Chalcolithic and Early Bronze Age occupation at Pınarbaşı

The Chalcolithic/Early Bronze Age occupation phase at the site was identified in all excavated areas and dates to the 4th millennium cal. BC (Table 3.5, see also Figures 3.7, 3.8). Remains of cereal crops (bread and glume wheat, hulled barley and lentils) alongside *Amygdalus* and *Pistacia* nutshell and *Celtis* stones were recovered. Previously reported wood charcoal finds include *Amygdalus*, *Pistacia*, *Tamarix*, *Fraxinus*, *Artemisia*, *Rhamnus*, *Celtis*, *Juniperus*, Leguminosae and (very rare) *Quercus*.

3.2.2 Boncuklu (Baird et al. 2012, Baird forthcoming)

The aceramic Neolithic habitation at Boncuklu consists of a small höyük located ~9.5 km to the northeast of Çatalhöyük on the northern edge of the Çarşamba alluvial fan and is dated to ~8.4-7.4 ka cal. BC (Figures 3.9-3.10, Table 3.6). The site displays clear cultural affinities with the 9th millennium occupation at Pınarbaşı and with the aceramic phases at Can Hasan III and Çatalhöyük. The occupation comprises a number of oval and round, semi-subterranean mudbrick buildings with ground-level entry and extensive midden and outdoor activity areas. Buildings were frequently repaired and rebuilt in a superimposed fashion, similar to practices at Çatalhöyük East. In addition, floors and walls were plastered with locally available marl-rich sediments with occasional use of red paint decorations, a practice commonly observed in Neolithic occupations in the Konya plain. Burials (with some exceptions) were intramural and subfloor with some indication of secondary or disturbed burials. Inside buildings space is divided into ‘clean’ (southeast) and ‘dirty’ (northwest) areas with much of the daily activities taking place in the northwest portion of the buildings, where the main hearth is also located. Symbolic elaborations including plaster features, bucrania installations and painted walls are generally restricted to the clean areas, as are all the burials. Reed mats and several small-size postholes are found inside buildings.

The lithic industry is dominated by obsidian, comprising several microlith types, though in the upper levels there are also some large projectile points. A prominent element of the stone technologies found at the site are incised and decorated ground stones, some of which might have been used as shaft straighteners, although some do not have an apparent functional purpose, but might have been used instead as portable decorated items of potentially symbolic significance. There are also several stone and shell beads, marine shells and unbaked clay objects.

The zooarchaeological assemblage comprises an abundance of waterfowl, freshwater fish and amphibians. A majority of the dietary meat input derived from *Sus* and *Bos* (*Bos* individuals on average larger than those found at neighbouring Çatalhöyük) while caprines are very rarely represented. Stable isotope evidence also suggests that local diets were meat-focused, with minor inputs from plant-derived foodstuffs. The animal assemblage also contains equids, cervids, *Canis*, *Vulpes*, *Lepus* and tortoise shell. Preliminary analyses of the stable isotope signatures of zooarchaeological remains at the site show that *Bos* at Boncuklu had an exclusively C3 diet, while nitrogen isotope values differ remarkably, perhaps reflecting two groups of hunted *Bos* occupying different ecological niches. Furthermore, analyses by Middleton (in Baird forthcoming) suggest that carbon stable isotope values for *Bos* are remarkably similar through time across the Konya plain ranging from the Epipalaeolithic (Pınarbaşı B) to the late aceramic Neolithic at Can Hasan III, indicating perhaps continuity in the grazing habits of the local wild *Bos* populations. Stable isotope signatures of (the very few) caprine remains at Boncuklu also suggest that these animals were grazing predominantly on C3 plants and their nitrogen values cluster closely with the lower nitrogen *Bos* group. Preliminary results of the analysis of the archaeobotanical assemblage attest to the ubiquitous presence, yet with very low abundance, of crop species including *Triticum monococcum, T. dicoccum* and some large legumes. In addition nut and fruit species were exploited including *Amygdalus orientalis/graeca*, *Pistacia* and *Celtis*. Seed, tuber and stem remains of *Bolboschoenus maritimus* are abundant, in addition to seeds, stem and rhizome fragments of *Phragmites australis*. Diverse wetland and dryland floras are represented with numerous finds of *Carex*, *Eleocharis*, *Alopecurus*, *Bromus*, *Adonis*, *Atriplex* and *Galium*. Wood charcoal finds (reported in detail in the Chapter 5) are dominated by Salicaceae.

3.2.3 Can Hasan III (French et al. 1972, Payne 1972, Hillman 1978, Willcox 1992)

The site of Can Hasan is located ~13 km northwest of Karaman, on the eastern half of the Konya basin (Fig. 3.10) and consists of occupation levels dated to the aceramic Neolithic and the Chalcolithic. The aceramic Neolithic occupation of Can Hasan III was uncovered in trench 49L and is dated to 7.6-6.6 ka cal. BC (re-evaluated radiocarbon dates; cf. Thissen 2002; Table 3.7). The site consists of rectangular mudbrick structures with mud-plastered walls and floors, which are sometimes painted red. The lithic industry has been identified as similar to early Neolithic assemblages elsewhere (e.g., Suberde, aceramic levels at Çatalhöyük; see discussion in Carter et al. 2005) comprising predominantly points, scrapers and several types of blades made from obsidian, and some flint sickle-blades. The subsistence economy relied primarily domesticated cereal and legume crops (*Triticum monococcum*, *T. dicoccum*, *Triticum* cf. *aestivum, Hordeum vulgare* var. *nudum*, *Lens culinaris*, *Vicia ervilia,* and possibly *Secale cereale*) and herded caprines. Various small-seeded wild legumes and grasses and several Cyperaceae were also reported. Wild fruits included *Celtis cf. tournefortii*, *Prunus, Crataegus and Vitis sylvestris* (wild grape). The faunal assemblage comprises *Ovis*, *Capra*, *Bos*, *Cervus*, equids, *Sus*, *Lepus* and canids, alongside a wide range of rodents, small mammals, waterfowl and amphibians.

3.2.4 Çatalhöyük East (Mellaart 1967, Hodder 1996, 2000, 2005a-c, 2007, 2013a-c, 2014, Conolly 1999, Fairbairn et al. 2002, 2005, 2007, Asouti 2005, 2013, Carter et al. 2005, 2006, Cessford 2005, Russell and Martin 2005, Pearson et al. 2007, Tung 2008, Twiss et al. 2008, Roberts and Rosen 2009, Bogaard et al. 2007, 2013, 2014a,b, Henton 2010, 2012, Ryan 2011, Doherty 2013, Nazaroff et al. 2013, Pearson 2013, Russell et al. 2013, Shillito et al. 2013, Yalman et al. 2013, Wright 2013, Filipović 2014)

Çatalhöyük is located in the Konya plain, near the modern town of Çumra on the centre of the Çarşamba river alluvial fan (Figures 3.10, 3.11, 3.12). The Neolithic höyük (east mound) is one of the largest in Southwest Asia (~13 ha) and was occupied between ~7.2-6ka cal BC (Table 3.11). It was formed by the superimposed rectilinear mudbrick structures, built in agglutinated ‘neighbourhoods’ that typify late aceramic and ceramic Neolithic habitations in central Anatolia. Successive excavations at the site have identified several occupation phases: 12 levels (I-XII) as identified by Mellaart’s excavations and 14 levels (G-T) in the South Area, 5 levels (F-J) in the North area and 7 levels in the TP (M-S) identified by the Hodder excavations (for the location of each excavated area and a summary of the stratigraphy and associated dates see Fig. 3.11,

Table 3.11). Due to the complexity of the mound formation and subsequent erosion, understanding the true extent of the site throughout the different occupation phases and correlating stratigraphic sequences across the different excavated areas has been one of the aims (and major challenges) of the ongoing excavations at the site. To date, there are still unresolved matters with regard to the precise dating of each phase/'level', the contemporaneity of building occupation within each phase and across different areas, and the depth and spatial extent of the earliest (aceramic Neolithic) phases of occupation.

Excavations to date have uncovered numerous, agglutinated mudbrick structures with entrances via the roof separated by open areas that were used primarily for refuse disposal. Alleyways, or narrow tracks on the ground level are very rare, thus suggesting that buildings were primarily accessed via the rooftops. It has been suggested that this agglomeration in building construction might be a strategy to provide more structural support to prevent subsidence and the slumping of mudbrick walls. Buildings were either demolished and/or burned (evidence for burnt buildings is limited to the later levels of the site) and new ones built on top, often adhering to the structure and plan of the previous building. In some cases, abandoned buildings were used as midden areas. Due to the potentially large size of the population at the site (estimates vary between 1600 to 16,500 individuals through the occupation of the site) and the long period of occupation, considerable variability is observed in building size, decorations, abandonment and rebuilding practices. Building sizes vary between 12m^2 to 59 m^2 and consist of a main room where activities such as tool-making, and food preparation and consumption took place and a side room used for food storage and some crop processing. Buildings were accessed through the roof, using a wooden ladder indicated through ladder imprints on wall plasters and (more rarely) the carbonised remains of ladder posts. Main rooms were fitted with ovens, hearths, symbolic installations (e.g., wall paintings, bucrania, reliefs, benches etc.) and plastered platforms often containing burials. Inhumations were intramural burials, inside platforms or sub- floor, and frequently comprised of the remains of more than one individual with evidence for both primary and secondary burials. The available data suggest that intramural burials (and associated burial goods) decrease over time. Towards the end of the Neolithic sequence and in the Chalcolithic occupation of the west mound this practice is replaced by extramural burials. Floor space was divided into 'clean' areas in the north, which contained much of the symbolic and ritual elaborations, and ‘dirty’ areas in the south (close to the roof entrances) where daily activities mostly took place. As mentioned already, considerable variability is observed in building structure; therefore ritual and symbolic elaboration is not always limited to the ‘clean’ floor areas. Likewise hearths and ovens are not always associated with the so-called ‘dirty’ areas.

There seems to be no direct link between the size of the building and the presence and frequency of sub-floor burials, symbolic installations, and storage features (e.g., plastered bins). This lack of differentiation has been taken as evidence of a distinctly ‘egalitarian’, communally organized society, which appears to be most pronounced in the earlier phases of the site gradually waning towards the later levels. Analyses of mudbrick production technologies and clay provenancing studies have detected no differences in style and procurement strategies, which could be linked to assumed differences in social status and ‘wealth’ accumulation. The only clear architectural trend is the shift to much larger buildings at the very end of the Neolithic sequence (i.e., the TP levels), which is matched by a higher degree of complexity in construction and more widely spaced, isolated buildings (after approximately level South P). Through the analysis of material densities in middens and buildings it has been suggested that middens were used by groups of buildings in close proximity. However, this correlation observed in midden accumulation and building deposits needs further evidence to support the use of specific areas by specific buildings. A case can be made for the sequence of buildings (65, 56, 44, 10) in levels South Q-T, which are likely to be linked to shared midden areas identified through excavation. This has also been supported with faunal evidence documenting the presence of specific pathologies in discarded bone remains in these middens, which have also been found in building 65. Towards the end of the sequence, concurrent with the larger building sizes, the amount of outdoor space accessible per building increases. This situation likely represents both a decrease in population density on the mound and a general dispersal of households across the available space, perhaps leading to the use of much thicker mudbrick walls and buttresses in building construction at the end of the sequence (TP levels).

Timber was frequently used, for the structural support of roofs and mudbrick walls. To date only a limited portion of the in situ preserved timbers have been studied and reported in full (cf. Asouti 2013). Not all excavated levels at the site include preserved carbonised timber remains, which are more abundant in the later levels of the site. The in situ timber posts and other structural wood elements were reported from Building 80 (South area) and Building 77 (north area). These findings, along with preliminary reports (cf. Asouti and Kabukcu unpublished field notes from the 2014 excavation season, Kabukcu and Asouti 2014) indicate that *Quercus*, *Juniperus* and *Ulmus* were the most frequently used timbers, while other taxa such as Salicaceae were also used. Dendrochronological analyses on *Juniperus* timbers from Mellaart's excavations by Newton (1996) remain the only other source of information on timber use at the site. Newton (1996: 9) reports the tree-ring sequences from *Juniperus* and *Quercus* posts and roof beams, noting the presence of some *Ulmus* timber elements as well. There are also some indications for the non-structural use of timbers in later phases (e.g., buildings 49, 55, 79 and 80) where the wooden posts are either asymmetrical, or do not extend to the full height of the preserved walls. This has been claimed as evidence for the presence of second storeys at Neolithic Çatalhöyük. However, recent finds from the study of *in situ* carbonised posts in building 80 (Asouti and Kabukcu unpublished field notes from the 2014 excavation season) have revealed that previously assumed plastered timber posts actually comprised short wooden stumps that supported fills of packing material and bricks and were subsequently plastered over to render the impression of a solid post. Such use of construction wood obviously calls into question the possibility of a second storey at least in some of the excavated buildings. Planned future analyses of all the timber remains available from the excavated East mound sequence will provide more information on the technology of timber use, the full range of taxa used as timber, as well as a useful comparison to the changes observed in wood fuel use at the site.

The artefactual finds at the site include ceramics, clay, stone and (very rare) wooden figurines, baked-clay seals, clay balls, wooden vessels, baskets, knapped and ground stone tools, bone tools and ornaments, beads (of various materials including shell, bone, clay, stone, mica, serpentine, etc.) obsidian mirrors and textiles. Fired pottery has not been found in the earlier Neolithic phases at the site (South G-I) and initially these finds are low density (South I-K) and appear to be made with local clay sources using relatively low firing temperatures. It has been suggested that during the earlier phases of pottery use (South I-M) cooking was not necessarily dependent on ceramics, or their use was infrequent. A non-local clay source, with better firing technology, used to make deeper vessels (in contrast to the shallow bowls of the earlier periods) becomes the dominant ware type after South M, a period which appears to represent a significant shift in daily activities across the site, reflected through shifts in several artefacts and ecofacts. In levels South Q-T and in the TP levels local clays are used again to produce wares, this time however with more efficient pyrotechnology. While pit firing using wood fuel (presumably complemented by other fuel types) has been proposed for later pottery production (e.g., after South M), it has been assumed that due to a presumed scarcity of wood fuel earlier pottery firing (e.g., South I-L) would have been achieved using open fires with ‘reed stem’ burning. While such a proposition remains to be tested, from a pyrotechnological point of view it seems unlikely that reed stems, which tend to flare up in short outburst (e.g. dying out in <5 minutes) and produce copious amounts of ash, would have provided a sufficiently stable temperature range for the required amount of time.

The lithic industry comprises mostly obsidian tools, sourced from Göllü Dağ and Nenezi Dağ in Cappadocia and some flint and chert. Tool types include projectile points, large flake scrappers, retouched blades and flakes, *pieces esquillés*, flint daggers and obsidian mirrors. The ground stone industry includes querns, hand grinding tools, axes/celts and polishing stones. While nodules for smaller ground stone artefacts might have been collected along the Çarşamba and May rivers, raw materials for larger slabs and boulders would have been collected from at least 25 km distance from the site. Karadağ was one of the sources of andesite and marble. There appear to be no notable temporal changes in the ground stone tools industry; some tools were manufactured on a household basis and were present in the repertoire of most buildings, although large grinding slabs are rather rare. Axes/celts, preferentially manufactured from bright green diabase, are among the standard toolkit in the household repertoire. While these small-size tools would not have been much use in tree felling, they were likely used in wood working.

Throughout the occupation of the site a wide range of crops and wild plant foods were used including *Triticum monococcum, T. dicoccum, Triticum aestivum, Hordeum vulgare* var. *nudum, Pisum sativum, Lens culinaris* and *Vicia ervilia*, and rarely hulled barley; wild fruits and nuts include *Pistacia, Amygdalus, Celtis, Ficus carica*, *Prunus* and (rarely) *Quercus.* Wild mustard *(Descurainia sophia*) is also present. In addition, *Cicer arietinum* and *Lathyrus sativus* were found in low abundance in the earliest phases (South G) and do not seem to have been used in great quantities during the later part of the sequence. Remains of hulled barley, on the other hand, become much more frequent after South Q and remain an important element of the TP and Çatalhöyük West sequences. In addition to crops, a very rich wild and weedy plant assemblage is reported at the site. A wide range of wetland taxa (e.g., *Bolboschoenus glaucus*, *Carex*, *Phragmites australis*, *Aeluropus*, *Salsola*, etc.) and some small-seeded dryland taxa (e.g., *Artemisia*, *Chenopodium*, etc.) comprise important elements of the archaeobotanical assemblage and may have been incorporated into deposits as elements of dung burned as fuel. Reeds were also extensively used in basketry, and as cordage and building materials.

The results of recent crop stable isotope analyses and the study of functional weed ecology suggest that crop cultivation took place in the vicinity of the site, likely in the form of intensive horticulture. Previous hypotheses had suggested that due to the unfavourable conditions on the annually flooded alluvial plain, farming would have been limited to the Neogene limestone terraces on the outskirts of the plain (Roberts and Rosen 2009). More recent evidence on the geomorphology of the sediments around the site (Doherty 2013) indicates that the marl deposits of the Konya paleo-lake are of variable thickness interbedded with the underlying Pleistocene sand deposits, which would have created relatively well-drained soils in the immediate vicinity of the site (within a 5 km radius) that could sustain agricultural production. This interpretation also appears to be supported by preliminary evaluations of strontium isotope signatures in crop remains and sheep teeth which indicate relatively local agro-pastoral management practices (Bogaard et al. 2014b).

The zooarchaeological assemblage at Çatalhöyük East is overwhelmingly dominated by remains of domesticated *Ovis* (and less so of *Capra*) across the site and through its different phases. The abundance of *Ovis* increases with time and their management becomes more intensive, especially after South P. In addition to caprines, a significant component of the faunal assemblage consists of wild *Bos* in the earlier periods. Interestingly, there is no evidence for cattle being domesticated locally. Instead, domesticated cattle were introduced at Çatalhöyük (after South O). A range of other taxa including equids, *Cervus*, *Dama dama* (fallow deer), *Capreolus* (roe deer), *Sus scrofa*, *Ursus* (bear), *Canis*, *Vulpes*, *Meles*, *Felis*, *Lepus*, etc. Isotopic studies confirm that animal protein formed an important part of the human diet, while taphonomic and spatial analyses of faunal remains suggest that caprines were mostly consumed as part of household activities; other wild and larger animals contributed to feasting activities and communal food consumption. In addition, numerous wetland birds, eggshell and amphibian remains contributed to local diets and subsistence.

Isotopic evaluations of the caprine diet suggest that C4 plants made a significant contribution to the diets of caprine herds in the earlier phases (South G). Mid-sequence caprine diets seem to be increasingly influenced by C3 plants (South H-P). By the end of the Neolithic sequence (South R-T), while there is considerably more variability within the caprine assemblage, C4 plants once more contribute significantly to caprine diets, thus resembling the pattern observed in the early phases. A comparable temporal shift in caprine diets (and thereby also in caprine herding practices) was observed in oxygen isotopic values and wear patterns of caprine teeth. This evidence suggests that during the early part of the sampled sequence (South G-M) caprines consumed mostly dirty, fibre-rich diets, whereas during the latter part of the sequence (South R-T) they were consuming clean, fibre-rich diets. Therefore, it appears that through time caprine herding became overall more extensive and varied (i.e., resulting in a wider range of isotopic signatures) whereas some herds were grazed further away from the wetlands and cultivated fields around the site, in dry grasslands on the plain.

Previously reported wood charcoal evidence has indicated that a broad range of trees and shrubs from the Konya plain and from locations further away from the site on the Taurus foothill zone were exploited during the Neolithic occupation of Çatalhöyük; *Quercus* is particularly prominent in the earlier ceramic Neolithic phases while *Juniperus* is more abundant in the mid-late Neolithic phases alongside the continued use of riparian woodlands throughout the occupation of the east mound.

In line with the above reviewed evidence for temporally varied, intensive and extensive use of the landscape for a wide range of activities, including trade networks that reached Cappadocia in the east and the Mediterranean coast in the south, evidence from the study of human remains indicates high mobility of individuals of both genders (Larsen et al. 2015). Through time, there is evidence for population increase during South M, N and O, followed by a later decrease, although this reflect (at least in part) varying sample sizes resulting from limited excavated areas, especially in the aceramic levels of the site; further analyses from the later and earlier part of the sequence could change this picture. The latest sampled part of the excavated Neolithic sequence (after South P) also indicates an increasing level of mobility and physical activity in adults.

3.2.5 Çatalhöyük West (Mellaart 1965, Gibson and Last 2003, Biehl et al. 2012, Bogaard et al. 2013)

The Chalcolithic Çatalhöyük west mound lies just 300 metres to the west of the Neolithic east mound (Figure 3.11) and dates to ~6ka-5.5 ka cal. BC (a single date is available from core CH96W near the base of the mound: AA-27981 -7040 ± 40 uncal. BP, 5930 ± 50 cal. BC at 1σ; Gökturk et al. 2003). In some ways, Çatalhöyük West displays significant changes compared to the Neolithic occupation, but in other aspects continuities can also be detected. The most significant change is observed in pottery production, which in the west mound includes red or brown-painted wares produced at the household level involving mostly low degrees of craft specialisation. Rectilinear mudbrick buildings continued to be built, similar to the latest occupation phases exposed in the TP levels of the east mound. However, west mound buildings were constructed with wider walls and mudbrick buttresses and might have contained two storeys, or a basement, and a central hearth. Such central hearts are also documented from the top of the east mound occupation (e.g., 4040J, building 47). Therefore such changes observed in building organisation may reflect a long-term shift in architectural practices beginning in the late Neolithic. Internal decorations and symbolic associations seem to have been less pronounced in the west mound, though there is some evidence for the use of red ochre on walls. Instead, it appears that there were more decorated portable objects.

Similar to the east mound, a majority of the lithic industry consists of obsidian tools, sourced from Nenezi Dağ and Göllü Dağ, alongside some flint and chert. The lithic industry comprises mostly unipolar blades and very few projectile points, a trend that also resonates with the TP levels on the east mound. This shift in the lithic industry is reflected in the faunal assemblage as well, which contains very low frequencies of hunted fauna. In addition, the zooarchaeological assemblage contains more caprines, while cattle bone seems to be less prominent. Archaeobotanical analyses are ongoing; however, it seems that the assemblage is similar to the end of the Neolithic occupation on the east mound, while hulled barley appears to be more important in the west mound habitation.

3.3 Summary

The time period under study in the present thesis not only spans a series of abrupt climatic fluctuations in the region, but also covers a period of significant transformations in the social, cultural and economic organisation of the communities inhabiting the region. The sites included in the study reflect the full spectrum of human lifeways in south-central Anatolia during this period encompassing mobile foragers, sedentary and/or semi-sedentary late forager/early farmers, and settled agropastoral and mobile and/or semi-nomadic pastoralists. These significant differences in the mobility strategies and subsistence socioeconomics of the studied sites, all of which are located in close proximity to one another, permit the investigation of their different fuel economies tied into socio-economic and micro-environmental variables within a closely controlled chronological and ecological framework. The next chapter provides a detailed account of the method, theory and practical applications of anthracology, with particular emphasis on the study of fuel wood macrobotanical remains, their ecological and socioeconomic interpretation.

CHAPTER 4. ANTHRACOLOGY: TAPHONOMY AND METHODS

The main aim of this chapter is to outline in detail the formation processes affecting wood charcoal assemblages (wood use, deposition of debris, burial and disturbance after burial) and how these remains are recovered on site, analysed and interpreted. The chapter will be presented in four sections, covering the taphonomic processes affecting the formation of archaeological wood charcoal assemblages, theoretical concepts on fuel wood collection, the quantitative and qualitative methods used in anthracology and, finally, the methods of quantification and statistical analysis employed in the present study. Wood and other products of trees are used for a wide range of purposes including fuel, leafy fodder, materials for tanning leather (e.g., bark, acorns), timber, tools, decorative and ornamental artefacts, furniture, etc. A majority of these ecofacts and artefacts are rarely preserved, especially in the form of carbonised wood, as their routine uses and discard do not always involve combustion. As this project is predominantly concerned with fuel wood, the focus will be on understanding charcoal assemblage formation processes, taphonomic constraints and the interpretation of fuel wood debris found in archaeological sites.

Charcoal analysis (anthracology) involves the identification and examination of carbonised wood remains relying on the observation of their three-dimensional anatomical structure. The earliest known identifications of wood macrofossils were carried out in the 19th century by Unger (1849) and later by Heer and Passerini (in Pigorini 1865) (see also commentaries by Castelletti 1990, Paysen 2012). In the following decades through to the early twentieth century macrobotanical identifications, including carpological and anthracological remains, became more widespread (Maby 1932). In the first half of the twentieth century methods of wood and charcoal identification were becoming more efficient. Initially, specimens were impregnated with resin and thin sections were obtained from resin blocks for examination using transmitted light microscopy. However, some researchers (e.g., Maby 1932, Grimes and Hyde 1935) had started using less time-consuming techniques whereby charcoal fragments were not resin-treated; instead they were hand-sectioned to obtain a fresh, clean break and examined with a hand lens or under a low power, binocular microscope, which also reduced the cost of analysis and enabled the identification of several fragments with ease. By the second half of the twentieth century, this technique had become a standard and (with the adoption of darkfield, reflected light microscopy) much higher numbers of wood charcoals from a range of sites and contexts could be analysed as a result (cf. Couvert 1968, Western 1969, 1971, Leney and Casteel 1975, Vernet et al. 1979).

Along with these methodological developments and the first publication of comprehensive wood anatomy atlases (e.g., Greguss 1955, 1959) interest in vegetation history and pollen analysis also increased, fuelled in part by an increasing awareness of human impacts on the environment, historic and prehistoric (Godwin 1956, Smith 1970). One of the earliest studies to explore the potential of wood charcoal assemblages for inferring prehistoric vegetation dynamics was the publication of the wood charcoal assemblage from Maiden Castle (Dorset) in Britain (Salisbury and Jane 1940). Salisbury and Jane (1940) combined species identifications with the examination of growth ring morphology (i.e., growth ring size and estimated log dimensions) and argued that the proportions of species observed in the assemblage, mostly deriving from fuel wood, reflected to some degree prehistoric woodland composition around the settlement. Their particular emphasis was on the issue of fuel wood availability and selection. Based on the evidence for the presence of a majority of branch wood and twigs in the charcoal assemblage, they argued that fuel wood was collected in the environs of the settlement and that it was ‘non-selective’ (i.e., collected without regard to the burning properties of the different species of wood). Their interpretations were heavily criticised by Godwin and Tansley (1941) who stressed the importance of cultural parameters determining the selection of wood for fuel and argued that anthracological assemblages, as a result of selection bias, could not reflect prehistoric vegetation accurately. Thus, one of the perennial debates in anthracology started and continues to this day: how representative are the remains of fuel wood debris with regard to past vegetation cover? In addition, Godwin and Tansley touched upon three important concepts in the interpretation of charred fuel wood macro-remains: collection (selective vs. non-selective), the impact of taphonomic processes and their quantification potential.

With the increasing emphasis placed on sampling strategies as a result of the proliferation of processual theories and methodologies in archaeology, and the introduction of water-assisted recovery techniques, a wider range and higher abundance of plant macrofossils from archaeological sites were becoming available (Pearsall 2000:

14). With the advent of radiocarbon dating methods the second half of the twentieth century also saw an increase in the detection and collection of wood charcoal macrofossils. These developments resulted in the application of new methodologies in anthracology including stricter sampling strategies and protocols, a renewed interest in prehistoric vegetation dynamics, and an increasing number of charcoal analysts working in various parts of the world in the 70s, 80s and 90s (see overviews by Chabal et al. 1999, Figueiral and Mosbrugger 2000, Asouti and Austin 2005, Théry-Parisot et al. 2010a).

In Southwest Asia, the systematic application of routine plant macroremain analysis in archaeological sites began in the 1960s and 1970s and coincided with an increasing research interest in the origins of plant cultivation and associated environmental change (Helbaek 1969, Hillman 1972, 1978, Willcox 1974). From its earliest applications anthracology in this region, unlike Europe, was far more engaged with questions of prehistoric climate change and vegetation dynamics (e.g., Kayacık and Aytuğ 1968, Willcox 1974, Western 1969, 1971). In Anatolia, the identification by Kayacık and Aytuğ (1968) of carbonised wooden structural elements at Gordion, which included juniper and oak, prompted these scholars to revise the prevalent ecological perceptions of central Anatolia as a ‘treeless steppe’. More charcoal analysts and botanists working in the region including Aytuğ (1970), Willcox (1974) and later Şanlı (1989) increasingly considered wood charcoal macro-remains as proxies for prehistoric vegetation cover, especially with regard to understanding human impacts on the landscape during the mid-late Holocene.

In the following sections the various taphonomic processes affecting assemblage composition (section 4.1), and the main theoretical concepts and methodological approaches pertaining to the representativeness of wood charcoal remains (section 4.2) are discussed in more detail alongside experimental work, ethnographic and ethnoarchaeological research. These concepts and associated methodologies developed to a great degree during the last three decades, building on earlier concerns and debates expressed in the field of anthracology. The chapter closes with a review of the principal methodologies involved in the sampling, subsampling and quantitative and qualitative analysis of anthracological remains (section 4.3).

4.1 Taphonomic processes affecting fuel wood

Deriving from the Greek words *taphos* (burial) and *nomos* (law) the term ‘taphonomy’, literally translated as the ‘law of burial’, is widely used in archaeological studies concerning the analysis of organic materials. Strictly speaking the concept of taphonomy refers to processes affecting an organism after its death until its preservation via fossilization, including burial (Efremov 1940, 1953). The way in which this concept is applied in archaeobotany however is often not limited to the natural processes which affect fossilization, but also includes factors relating to cultural decision-making which define patterns of use and deposition of plants (i.e., processes prior to burial). It also includes routine activities, processes and other events that transform burial conditions (e.g., post-depositional disturbance after carbonisation) (cf. Asouti 2005, Thiébaut et al. 2010, Théry-Parisot et al. 2010a). In part, this emphasis on behavioural patterns and the detection of specific activities in the anthracological record has been fuelled by earlier concerns over the representativeness of fuel wood remains with regard to fuel use and, more importantly, past vegetation cover. Therefore, taphonomic studies of fuel wood remains have been expanding, with an increasing body of experimental work demonstrating the various cultural and environmental (non-cultural) filters that alter the composition of archaeological fuel wood assemblages before and after burning, thus allowing us to understand better fuel wood use and depositional processes (Théry-Parisot et al 2010a-b, Thiébaut et al. 2010, Chrzavzez 2013). Of these various filters, only carbonisation (i.e., charcoal preservation) and subsequent post-depositional processes are discussed in this section (4.1). Filters relating to fuel wood selection and collection, species availability and vegetation dynamics as reflected in anthracological assemblages will be discussed under section 4.2. The reason is that those processes (relating to pre-depositional filters) are variously determined by socio-cultural elements. Processes of carbonisation, practices of discard and various post-depositional disturbances (e.g., surface exposure, trampling, weathering) rely more (if not exclusively) on exogenous factors (i.e., factors unrelated to wood physiology, anatomy or chemistry) which can be deduced through a close examination of experimental and ethnoarchaeological case studies and archaeological context-related variation.

4.1.1 Carbonisation: morphological and anatomical effects, temperature, moisture content, hearth function and structure

The great majority of plant macro-remains found in archaeological sites are preserved in carbonised form and therefore have come into contact with fire either intentionally or accidentally. Once heated, woody tissues thermally decompose; if there is a sufficient supply of oxygen the volatiles that are released as a result of heating will ignite and kick-start the burning process. It is only in the absence of an adequate amount of oxygen that the combustion process will be interrupted and wood tissues (and other plant macro-remains) will be preserved as charcoal (Beall 1972, Braadbaart and Poole 2008). Carbonisation occurs at temperatures ranging between 280°-500°C (Beall 1972) while a majority of the mass loss of woody tissues (~60%) occurs in the early stages of this process, in temperature ranges between 220°-310°C (Braadbaart and Poole 2008). Depending on the length of exposure and the maximum temperatures of the fire, mass loss of wood tissue during carbonisation can reach anywhere up to 85%.

Until recently, charred macrofossils were thought to be composed of mostly inert carbon, which would render them durable to decomposition resulting from burial conditions. However, recent research (Cohen-Ofri et al. 2006, Braadbaart and Poole 2008, Braadbaart et al. 2009, Huisman et al. 2012) has shown that the major components of wood tissues (cellulose, hemicellulose and lignin) are converted into benzenoids. These aromatic compounds are known to be unstable in alkaline conditions and are therefore subject to further decomposition after carbonisation, quite independently of other depositional and post-depositional variables. Such alkaline conditions could be prevalent in archaeological contexts if burnt plant debris was discarded together with the accompanying ash from fires (ash is predominantly alkaline, containing a significant amount of calcium and potassium oxides). Furthermore, Rebollo et al. (2008) demonstrated through experiments under different pH conditions that soil alkalinity results in the degradation and fragmentation of wood charcoals, while acidic soils might also result in the accumulation of mineral deposits on charcoal particles. Further evidence for decomposition and degradation of carbonised remains is provided by Scott (2010) and Ascough et al. (2011). These authors report that, as a result of oxidising conditions, the graphitic components of wood charcoal degrade with time into materials chemically and macroscopically similar to humic acids.

Even though combustion has an effect on the macroscopic appearance of wood, the majority of its microscopic anatomical features and internal structure survive this process. In addition to mass loss and discolouration, carbonisation may also result in radial and tangential cracks or fissions in wood as a result of rapid moisture release and chemical reactions during burning (Beall et al. 1974, Zicherman and Williamson 1981, Théry-Parisot et al. 2010a, Théry-Parisot and Henry 2012). Volumetric shrinkage is observed in all three anatomical planes (see also Figures 4.1, 4.2) of wood tissues, with usually more pronounced reduction in the radial longitudinal plane. In some cases wood charcoal might exhibit a vitrified (glass-like) preservation state. Various ideas have been put forward in trying to understand the causes of vitrification, including exposure to very rapid carbonisation involving very high temperatures (Prior and Alvin 1983, Fabre 1996), the burning of green wood (Thinon 1992, Talon 1997) and the re-firing of charcoal (Fabre 1996). However, experimental work testing these various hypotheses has not been able to replicate vitrification (Pye and Ancel 2006, McParland et al. 2010). Hypotheses regarding the causes of radial cracks in wood charcoal have also been tested (Théry-Parisot and Henry 2012) and no obvious positive correlations were found linking moisture content of wood and the occurrence of radial cracks. On the other hand, radial cracks may relate to the seasoning of fuel wood and can become further pronounced as a result of burning (Théry-Parisot and Henry 2012). Prior and Alvyn (1983) have also observed that the incidence of radial cracks is higher in taxa with very wide rays (e.g., oak).

A wide range of fire features, both indoors and outdoors, including expedient features with light construction, complex large ovens, and stone, mud or plaster-lined hearths have been documented in various ethnographic and archaeological studies. Fire installations can be used for cooking, heating, manufacturing purposes, waste disposal, and ritual/mortuary purposes. As a result, the residues left behind by such varied activities involving fire use can be extremely variable in quantity and type. One pertinent result of all types of fire features is that the majority of fuel used in them will be converted into ash, as most fires will run at temperatures upwards of 500°C. A majority of the preserved carbonised residues were either buried in the ashes, therefore becoming insulated and cut off from oxygen supply, or were pushed to the edges of the fire and cooled before reaching the stage of complete combustion.

It has been postulated that wood from small-size woody species (e.g., shrubs, climbers, woody herbs) that are often used as tinder is more likely to be completely turned to ash, therefore producing no wood charcoal or of sizes too small to be identifiable (Smart and Hoffman 1988). According to Smart and Hoffman (1988) the size of logs used in a fire and their placement in a hearth largely determine the amount of charcoal produced. They observed that pieces coming from larger logs and those placed along the edges of the fire have a higher likelihood of carbonisation. However, various other experiments have not been able to demonstrate a general rule explaining the rate of charcoal production in a fire (Théry-Parisot et al. 2010a-b). Based on fire experiments Rossen and Olson (1985) have also suggested that softer woods (e.g., willow and poplar) tend to break down into smaller fragments and/or reduce to ashes easier compared to denser woods (e.g., oak, elm and ash) (see also ranking of fuel woods by Boulton and Jay 1946: 112). However, such distinctions do not take into account the impacts of other filters (e.g., moisture content and burning environments/hearth types) in wood carbonisation. Controlled carbonisation experiments by Shackleton and Prins (1993) also suggested that mass loss during burning is not uniform for all woody taxa. Nevertheless, these authors did not find a significant relationship between the amounts of charcoal (measured by weight) obtained at the end of the experiment and the diameter of the logs used, or wood density. It should be noted here that these experiments were conducted in a temperature-controlled muffle furnace for a set amount of time; therefore they do not approximate the taphonomic conditions affecting wood burnt in actual fires.

4.1.2 Deposition and post-deposition: practices of fuel waste discard, burial conditions, bioturbation

The processes impacting on the survival of fuel waste debris following carbonisation relate to practices of deposition (hearth type), re-deposition (discard), recycling, weathering and trampling by people and animals. In addition, burial conditions (e.g., soil moisture, surface exposure, and freeze-thaw cycles) and disturbance by burrowing animals also result in further fragmentation and disintegration of charred plant remains.

Hearth type and use, and manner of hearth construction have a significant impact on the preservation of charred macro-remains (Ntinou 2002: 115-120). Open, outdoor fire features with or without mud or plaster bases tend to be easily spread over a larger area and various types of fuel and food waste get mixed (Binford 1983, Engelhardt and Rogers 1998). When these features are reused, their centre shifts and much of the burnt debris is scattered (Binford 1983). In most hearths, reuse also results in the compaction of fuel waste debris at the base of the feature. As a result of all these factors, it is very difficult to separate individual fire episodes.

Indoor fire features and more permanent outdoor fire features (e.g., lined hearths, outdoor ovens etc.) tend to be cleaned more regularly (O'Connell et al. 1991, Zapata et al. 2003, Meyer 2003). Routine cleaning of indoor fire features (e.g., domestic hearths and ovens) is necessary for the maintenance and efficiency of the installations, as accumulated ashy debris would make it more difficult to contain and control the fire. Ashy oven or hearth rake-outs may be discarded in a variety of locations including primary (undisturbed) to secondary (re-deposited) refuse pits and/or middens containing fuel waste (O'Connell et al. 1991, Engelhardt and Rogers 1998). Observations of fuel waste discard at Hadza residential base camps by O'Connell et al. (1991) revealed that while most of the fuel waste debris (along with other types of refuse) was discarded in off-site locations, occasionally waste materials were deposited just outside hut entrances. Based on ethnoarchaeological evidence from an abandoned Maasai settlement in East Africa, Shahack-Gross et al. (2004) suggested that off-site locations should be investigated for trash pits and midden areas containing ashy fuel waste, especially in pastoralist and hunter-gatherer encampments. Ethnoarchaeological research in northern Morocco has also demonstrated the variability observed in fuel waste discard practices. For instance, while in some cases fuel waste is discarded in middens or used as fertilizer for gardens, sometimes the ashy fuel waste is sieved and the large pieces re-used in fires (Zapata et al. 2003, Peña-Chocarro et al. 2005). Following certain activities which result in the preservation of substantial quantities of charcoal, such as pottery firing or bread-making, the larger pieces of charcoal are collected and stored alongside wood to be re-used as fuel (ibid.)

Considering the impacts of all the aforementioned parameters on charcoal taphonomy, the question arises as to whether archaeological charcoal assemblages may be considered representative of the actual proportions of fuel wood used in the past. Various statistical studies of charred wood assemblages alongside experimental and ethnoarchaeological studies suggest that this might be the case. Chabal (1988, 1992) has previously suggested that burnt wood produces charcoal in a random manner, resulting in a low number of large fragments and a high number of small fragments regardless of taxon-specific differences in anatomy, and wood density and size. This assessment of the fragmentation behaviour of wood charcoal assemblages was based on statistical analyses evaluating the correlation between mass loss and fragmentation in archaeological wood charcoal populations (Chabal 1992, Chabal et al. 1999). Chabal discovered that in most cases wood charcoals of each taxon are present with high counts of small fragments (<2mm) and low counts of large fragments (>4mm) in a given anthracological assemblage (see also Fig. 4.3). Chabal established that in anthracological assemblages, when random samples from each discarded fuel waste deposits (e.g., middens and other types of dispersed contexts; cf. *charbon de bois dispersés* Chabal et al. 1999) are examined, the weight frequency distribution and fragment number distribution of each species correlate closely, and can be further controlled by strict sampling and subsampling protocols to produce representative results (Chabal 1988, 1992, 1997, Chabal et al. 1999). These observations provided the justification for using fragment counts instead of weights for calculating the relative proportions of the taxa used as fuel in the past. As a result of Chabal's observations, counting charcoal fragments is now the most widely accepted and frequently used method in taxon determining frequencies (Chabal 1988, 1992, 1997, Heinz 1990, Badal-Garcia 1992, Asouti and Austin 2005).

While evaluating the proportions of the taxa used as fuel in the past on the basis of charcoal fragment counts or weights seems reasonably well established, it is still not completely clear as to whether these two indices (measured in experimental samples, or recorded in archaeological wood charcoal samples) accurately reflect the volume and quantities of wood used as fuel. The numerical evaluations of Chabal were concerned with archaeological charcoal assemblages (not fire experiments or other controlled situations) that she correctly identified as representing the combined effects of various filters, including depositional and post-depositional fragmentation and mass loss. Numerous experiments by Théry-Parisot et al. (2010b), Lancelotti et al. (2010), Chrzavzez (2013) and Chrzavzez et al. (2014) were subsequently conducted for testing Chabal's hypotheses further. Théry-Parisot et al. (2010b) conducted repeated fire experiments in identical features with temperatures continuously recorded through the duration of the fire, using a single species in each fire experiment. The carbonised wood fragments were collected at the end of each experiment, sieved into different size fractions (>4mm, 4-2mm, <2mm) and counted in order to assess the fragmentation indices of each species. The purpose was to evaluate: (a) the representativeness of fragment counts (whether they reflect the original quantities of wood placed in the fire), and, (b) the effects of taxon-specific properties (wood density, chemical composition, anatomy, etc.) on rates of fragmentation. The authors found no significant correlation between species-specific variables and the fragmentation rates of wood charcoal. Interestingly, when the entire experimental assemblage was quantified based on fragment counts (295,688 fragments of >2mm charcoal, produced from 110 controlled fire experiments) the results also confirmed the original relative proportions of species used as fuel for 6 out of the 11 species selected for these experiments (see also Théry-Parisot et al. 2010b: 86 & Figures 4-6).

Chrzavzez (2013) conducted a different series of repeated experiments, this time testing the post-depositional fragmentation of wood charcoals. She used equal numbers of charcoal fragments from each taxon, for evaluating the rates of fragmentation of different species under surface weathering conditions, freeze-thaw cycles, mechanical pressure and wet-dry cycles. She reported that of all the species tested oak and beech charcoal produced the highest number of fragments, especially in <2mm size fractions (Chrzavzez 2013: 293-298 & Figures 152-155). As a result of trampling, surface weathering, freeze-thaw cycles and mechanical pressure a majority of >2mm fragments broke down into smaller size classes for all species included in the experiments (ibid). In most archaeological wood charcoal assemblages <2mm fragments rarely preserve enough anatomical features to permit botanical identification. Conditions of repeated wet-dry cycles resulted in a very high proportion of <1mm charcoal fragments. Chrzavzez concluded that on the whole mechanical pressure causes the highest fragmentation rate; all experiments resulted in higher fragmentation rates among size fractions <2mm (Chrzavzez 2013: 306-312 & Table 39).

Overall, the above discussed studies of charcoal fragmentation experiments (involving both combustion and fragmentation caused by post-depositional processes) suggest that short-lived features and primary deposits buried rapidly after use are more likely to contain well-preserved charcoals including large fragments (>2mm) and rare taxa. Such contexts are also likely to be different in taxonomic composition compared to charcoal assemblages accumulated over long periods of time. The latter involve dispersed contexts (e.g., middens, '*charbon de bois dispersés*', Chabal 1992, Chabal et al. 1999) and are more likely to reflect, with some level of uncertainty, long-term patterns of fuel use. Both Théry-Parisot et al. (2010b) and Chrzavzez (2013; see also Chrzavzez et al. 2014) found that >4mm size fractions are the most representative with regard to the relative proportions of the wood originally burnt as fuel and the quantities of wood charcoal subjected to specific types of post-depositional alterations respectively. However, occasional differences did exist: of all the taxa included in the experiments conducted by Chrzavzez (poplar, hazel, pine, ash, oak, beech, maple, birch, juniper, hornbeam) oak charcoals produced the highest number of >4mm fragments, while poplar produced the least. Yet, the combustion experiments demonstrated that the taxa most intensively used as fuel still emerged as the most abundant ones in the resulting wood charcoal assemblages. Thus, as originally suggested by Chabal et al. (1999) and subsequently verified by the experimental analyses of Chrzavzez (2013) and Théry-Parisot et al. (2010b) concentrating on the analysis of fragments derived from the >2mm and especially the >4mm size fractions seems to provide the most reliable reconstruction of the relative proportions of the woody taxa used as fuel. Regardless of any discrepancies that may be observed in the carbonisation stage, depositional and post-depositional processes appear to impose a more or less even filter on charcoal fragmentation of different species. Therefore, using fragment counts as a method for reconstructing fuel species composition and relative proportions is justified.

With regard to the representativeness of particular types of archaeological contexts and deposits and the potential offered by their anthracological assemblages for palaeoenvironmental reconstruction, the most insightful and informative analyses come from spatially extensive, diachronic analyses of taxon distribution and charcoal fragmentation in archaeological sites (Chabal 1992, 1997, Chabal et al. 1999). These studies, beyond what experimental and ethnoarchaeological research can provide, allow us to assess whether long-term patterning is present and consistent at each site, in addition to permitting evaluating whether regional patterns can be captured through anthracology. As mentioned earlier, the statistical analyses on archaeological charcoal remains carried out by Chabal have indicated that post-depositional filters are more uniform where fuel waste debris is found dispersed (‘*charbon de bois dispersés*’ Chabal 1992: 216). Examples of such contexts are middens and building infills (especially if midden-like accumulation can be observed) and these have been termed ‘synthetic deposits’ (Théry-Parisot et al. 2010a). Contexts such as fire features (hearths, ovens, kilns, fire spots, etc.) represent ‘heterogeneous deposits’, likely to preserve a snapshot of a single firing episode (last phase of hearth use) (see also Table 4.1). Chabal (1992, 1997) advises that the focus should be on synthetic deposits if the goal is to obtain a diachronic view of vegetation use dynamics and its changes through time. The representativeness of each context can be assessed by whether or not it adheres to the overall charcoal assemblage composition of the same phase (or stratigraphic level) as reconstructed by so-called ‘dispersed’ contexts such as middens (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999). Concerning the palaeoenvironmental representativeness of anthracological assemblages (a topic which is discussed in greater detail in the next section) a useful guide is the correlation of charcoal sample composition with other palaeovegetation proxies (e.g., off-site pollen sequences).

Through detailed ethnoarchaeological investigations at the village of Sarakini (Thrace, Greece) Ntinou (2002) has also identified that primary fire features will tend to either contain the remains of the most recent burning event, or a very small amount of long-term accumulated fuel waste. The author further observed that ad hoc fire features (e.g. open fires next to seasonal work sites, or those on the edges of agricultural fields), tend to contain fuel waste debris reflecting the vegetation in the immediate vicinity of the hearth. As these tend to be features with minimal pyro-technological requirements and less labour investment, the fuel used in such features often reflects a resource maximisation scenario (Ntinou 2002: 115-120). On the other hand, more permanent and complex fire features, such as outdoor ovens and domestic hearths, contain a mix of preferred fuel sources and easy to collect ones. These features are cleaned on a regular basis and the debris deposited in waste disposal areas. The author’s analysis of the remains in waste disposal areas revealed that such accumulations of fuel waste debris (“dispersed contexts”, *‘charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) reflect a composite picture of fuel use in contemporary fire features (ibid.)

Two other post-depositional factors might introduce a bias into the representativeness of wood charcoal fragment counts or weights in archaeological contexts. These are permineralisation after deposition, and fungal decay and the rotting of wood before carbonisation. De Lafontaine et al. (2011) report that long periods of charcoal burial in soil might increase the amount of minerals deposited in the porous wood charcoal fragments, which may lead to heavier fragments thus impacting disproportionately charcoal weights. These authors also suggest that permineralisation could lead to increased resistance to post-depositional mass loss and degradation of charcoal particles thus affecting charcoal fragment counts. Such post-depositional formation processes could explain the dominance of heavily permineralised wood charcoal specimens at some archaeological sites (e.g., Kissonerga-Mylouthkia; cf. Asouti 2003b).

Uncharred wood tissue is subject to fungal or bacterial degradation which results in the breaking down and consumption of cell walls and lignin (for detailed examples see below, section 4.3.2). Wood tissues are subject to three different types of fungal attack. White rot fungi, caused by bacteria of the Basidiomycota family, lead to the near complete degradation and consumption of cell walls and lignin, resulting in a bleached discoloration of the wood tissue (Eriksson et al. 1990, Blanchette 2000). White rot fungi are common as parasites in the heartwood of living trees and do not lead to a significant loss of mechanical strength in the tree until the late stages of spread. White rot fungi are also effective decomposers of ground litter in forest biomes (Eriksson et al. 1990). Brown rot fungi (e.g., *Serpula lacrymans*) spread much faster in wood tissue and can colonise standing trees, dead wood and timbers leading to a rapid loss of mechanical strength. This rapid spread is possible with the proliferation of aerial mycelia, which can differentiate into strands and expand the fungal colony (Jennings 1991). The third type of fungal attack, soft rot, causes the secondary cell walls to collapse and, unlike white or brown rot, does not alter the main cell walls. Soft rot leads to the formation of a network of cavities and can result in rapid loss of strength (Blanchette 2000).

Experimental charring of fungi affected wood by Moskal-del Hoyo et al. (2010) and Théry-Parisot (2001) has provided new evidence on the preservation of remnants of fungal hyphae and spores in wood charcoal. These authors report that, in most cases, the alterations caused in wood anatomy as a result of fungal attacks, as well as the mycelium and deposits of crystal oxalate salts in vessel elements, can be identified after charring. Previously, microscopic observations of fungal hyphae were interpreted as post-depositional attack on the charcoal (Heiss and Oeggl 2008) whereas only imprints of fungal mycelia on vessel walls were considered to be reliable indicators of fungal infestation prior to charring. However, the experimental work of Moskal-del Hoyo et al. (2010) demonstrated that fungal hyphae can be preserved in charcoal, and the use of this criterion alongside other anatomical effects of fungal rot (e.g., collapsed vessel walls, crystal oxalates) may confirm the use of deadwood as fuel. The same authors suggest that preserved fungal hyphae directly attached to the cell walls of the wood can be safely taken as evidence of fungal attack prior to charring (Moskal-del Hoyo et al 2010: 211). The detection of fungal decay in archaeological wood charcoals could provide a basis for identifying the use of dead wood and/or recycled timber as fuel (e.g., Asouti 2005).

More recent work on the identification of different states of decay in wood by Henry and Théry-Parisot (2014) confirms that the various stages of fungal decay and rotting can be detected through the detailed study of the wood anatomical features of charcoal specimens. These authors report that the degree of cell deformation and the frequency with which such features occur in a charcoal fragment could be indicative of the degree of fungal and/or microbial decay of the wood before charring. In the most severe cases the dominant presence of fungal hyphae is accompanied by severe cellular deformation (collapsed and/or thin cell walls dominating the transverse section, alongside the occurrence of gaps and cavities in wood grain). Such criteria could be taken as indicators of whether deadwood was collected in earlier stages of decay or in the rotting stage. However, this particular study was performed only on conifer wood specimens from Siberia. Much more experimental work is necessary for establishing reliable signatures of fungal decay stages in hardwoods that are more common in temperate and semi-arid regions.

4.2 Fuel wood collection, species availability and palaeovegetation

The use of fuel is not always limited to domestic heating and cooking needs, especially when taking into account a range of activities which require different fire temperatures such as dairy processing and pyrotechnological industries including the production of fired pottery, metallurgy and other related industrial activities. Likewise, fuel selection, hearth type and fire debris discard practices do not always take shape in relation to environmental availability or serve the singular purpose of maximising energy returns; rather a wide range of economic and other decision-making strategies are involved (Asouti and Austin 2005). In many respects, within the field of anthracology quantification and methodological developments have not been matched with equal developments in theorising fuel selection and use. Often what is regarded as the rational interpretation of the empirical data provided by anthracological analyses may represent little more than a reductionist view of past fuel and timber use as opportunistic, optimal and cost-effective strategies of woodland exploitation by prehistoric societies. This stems predominantly from the wide acceptance of the Principle of Least Effort (PLE) in anthracology. The PLE is a generalist theory that was first proposed by George Kingsley Zipf (1949), who argued that all human behaviour is explained by the general rule that the least amount of effort is spent to obtain maximum returns. It has greatly influenced charcoal interpretation with its central assumption that fuel wood collection would take place in a relatively small area, close to the location of the settlement, and that all available woody species would be universally collected in direct proportion to their availability in the past vegetation (cf. Prior and Price-Williams 1985, Tusenius 1989, Chabal 1992, Shackleton and Prins 1992). More specifically, Shackleton and Prins (1992) proposed a PLE model of fuel wood collection (see also Table 4.2). Its key premise is that in high-density woodland environments fuel economies tend to be selective towards preferred wood fuel species, and are characterised by the routine collection of readily available dry deadwood in close proximity to habitation sites. By contrast, under conditions of wood scarcity, fuel economies tend to be non-selective: they target all available taxa regardless of their burning properties, and include deadwood and “greenwood” alike. Based on this theoretical foundation, PLE-inspired interpretations of anthracological datasets have proposed that (under certain methodological conditions) archaeological wood charcoal taxon frequencies may represent an accurate reflection of local woodland composition and its changes through time. They can thus be used a source of evidence for palaeoenvironmental reconstruction in a manner similar, if not identical, to that of pollen analyses (Chabal et al. 1999).

While there has been some debate concerning whether or not fuel wood collection is determined by cultural selection (i.e., culture-specific definitions of ‘good fuel’) or functional motives (i.e., maximising calorific and energy returns), this has not resulted in systematic theoretical approaches in this field, with some exceptions (e.g., Shackleton and Prins 1992, Asouti and Austin 2005, Dufraisse 2008, Picornell et al. 2011). Proponents of the primacy of culturally determined selection (e.g., Heizer 1963, Godwin and Tansley 1941, Smart and Hofmann 1988) have argued that wood collection is determined by preferences of prehistoric communities that depend on socio-cultural value systems. Therefore perceptions of the properties and suitability of fuel wood species tend to vary beyond functionally optimal behaviour patterns. Thus, it is argued that archaeological fuel wood remains cannot provide a sound inference on the local (or regional) availability and distribution of woody plants. A variant of this argument is that data based on quantified charcoal frequencies obtained from archaeological contexts cannot accurately reflect the entire spectrum of wood fuel use (e.g., Willcox 1974, 2002, Zalucha 1982, Smart and Hoffman 1988, Brady 1989, Piqué 1999). Therefore, any reconstructions of species availability would be at best partial. Moreover it was predicted that selective pressures on preferred fuel species would lead to their depletion, which would ultimately lead to a broad-spectrum fuel economy characterised by the use of low-ranked fuel species (Miller 1985). It was also suggested that the use of crop processing waste, dung, and difficult to harvest woody species (e.g., spiny shrubs) would occur predominantly in environments of wood fuel scarcity (ibid.)

One major issue with such views of fuel collection is that subsistence economy activities are perceived to occur in separation from fuel procurement and use. However, such a separation, real or perceived, is not born out of the available ethnographic studies (discussed below), with the partial exception of modern urban populations. In addition to this, whether fuel collection is selective or (environmentally or functionally) optimal, the concept of differentiating between botanical species might not have been such a significant factor. Systems of ethnobotanical classification do not always adhere to scientific botanical taxonomies (Cunningham 2001). Some people in the Konya area for example, refer to hackberry and terebinth with the same name, çitlembik, denoting possibly that both trees produce small fruits/nuts for snacking. While most botanical classifications also take into account overall differences in the phenotype of plants, culturally such differences may not be as important as the real or perceived similarities in the function of their products. For instance, the Alutiiq (Alaska) differentiate between different forms of driftwood collected, regardless of species: *pukilaaq* (small driftwood), *tep'aq* (driftwood log) (Drabek and Adams 2004).

Ethnoarchaeological work on fuel use by Picornell et al. (2011) in the Fang villages of Equatorial Guinea demonstrates the importance of economic and cultural parameters in determining fuel collection areas and the selection of fuel species. The evidence shows that fuel wood collection takes place not only within the immediate vicinity of the settlement, but rather in areas that are ‘socialised’ spaces. These areas (*tsií*: orchards, *ekot/mbut*: fallow land) are spaces in which the spirits of the animals, the plants and the ancestors do not roam. By contrast the rainforest (*afán*) is never used for fuel wood collection as it is considered as the home of the spirits. The authors argue that even though a concept of ‘good fuel’ exists (woods that are dense, burn slowly and produce little smoke) this does not translate in habitual preference for, and use of, such taxa. The ‘good fuel’ property is invoked only when extraordinary circumstances (short-term fuel shortages or requirements for special events) necessitate additional labour for wood procurement. Instead, the by-products of agricultural activities (woodland clearance for the establishment of new tree groves) are regularly used as a source of domestic fuel wood. By contrast, several wood species are never collected (even from cleared fields) because they are deemed to be ‘bad fuels’ due to cultural restrictions. This case study and several other ethnographic accounts (below) demonstrate that while fuel needs and patterns of use develop in response to everyday subsistence activities, at the same time they are also the results of locally determined strategies of fuel use and cultural perceptions.

Other studies have demonstrated that fuel wood collection management strategies may alter ‘natural’ species availability. Salehi et al. (2013) report on the collection of fuel and other economically important resources (leafy fodder, timber) by village communities on the Zagros Mountains in Iran. These authors report that the majority of mature *Pistacia* trees with diameter >50 cm grow in the immediate vicinity of the settlement and are intensively managed for the production of leaf fodder, while trees most commonly exploited for fuel have diameters <30 cm and are more numerous away from the habitation site. The larger trees close to the settlement are occasionally harvested as timber. Woodlands are also frequently used as pasture areas. The highest levels of botanical diversity occur in the least managed areas. By contrast, the largest trees and highest wood volumes are available in intensively managed areas closest to the settlement. Thus local economic strategies result in complex impacts on the structure, composition and ecology of woodland vegetation (Salehi et al. 2013).

Smart and Hoffman (1988) reviewing several ethnographic case studies, report that certain types of wood can be seasonally selected based on their burning qualities and also their availability. For instance, the Ingalik of Alaska choose spruce as their main winter fuel, and willow and poplar during the spring months when heat requirements are not as high. At the same time, alder is never used in indoor fires because its red sapwood is regarded as unpleasant. Other trees such as birch, elder and elm are avoided indoors since they produce a lot of smoke. On the other hand, many conifers are used as kindling due to their high content in resinous substances. They burn faster and with a stronger flame than many hardwoods. Real or cultural perceptions of the qualities of individual species may sometimes outweigh practical necessities. For instance, the Erenk of Siberia reportedly avoid using birch wood as fuel as they believe it to be harmful to humans; instead they use larch in various states (green, dead, rotting) for most fuel needs (Henry 2011). Therefore selective pressures may not always be exerted equally on the most abundant species in the landscape. In some cases, cultural distinctions of fuel preference may act as markers or ethnic, communal, or socio-economic boundaries, regardless of species availability. Along these lines, the Erenk (Siberia) for example, choose the location of their settlements partly based on the availability of standing dead larch trees in the vicinity. To view such cultural norms of habitation and resource use in a purely functional way (i.e., settlement location chosen based on the availability of particular wood species in the natural vegetation) would be misleading and simplistic. If this was the case, and energy returns rather than cultural factors were the driving factor behind fuel use and settlement location, the same group of people would not have a problem burning shrub species and birch wood.

In his study of the socio-economic aspects of fuel use in a Bangladeshi village, Briscoe (1979) reports on the uneven distribution of fuel types used by different households depending on their income and social standing in the village. While on the whole, collective fuel use seems to be focused primarily on agricultural by-products and crop residues, the more affluent households supplement their fuel needs with wood from trees in the village and wood purchased from the city bazaar. Other studies (Devres Inc. 1980) have shown that agricultural societies organise access to tree crops and woodlands according to individual or communal ownership. Systems of individual or communal tenure can incorporate gardens, patches of woodland surrounding cultivated plots or, in other instances, entire woodlands that are privately owned (Devres Inc. 1980: 13-15). Environmental availability is continuously modified by transplanting and woodland management practices. Changes through time depend more on perceived values of specific trees and the labour input required to maintain their productivity. Therefore diachronic shifts in the methods of firewood procurement, use and species preference could also reflect major shifts in modes of resource exploitation and, inadvertently in social organisation.

Other studies have drawn attention to the importance of proximity and access to woodlands. The patterns of fuel use in Kampong Thom province, Cambodia, from three villages with differing population densities and forest availability reflect how assumed strong cultural preferences for ‘good fuel’ may be better explained by proximity and access to woodlands and dense forests (Top et al. 2004). These authors point out that, settlements with access to more abundant fuel wood resources are less concerned with conserving forest resources. The diameter of the fuel wood used tends to be larger compared to the wood used by settlements located in environments with lower levels of woodland resource availability. In the latter, most people (80%) professed that they do not select for specific types of fuel. Easily collected deadwood was unanimously reported by all communities to form an important component of the fuel economy (contributing to ~30% of the fuel economy) regardless of socio-economic status, woodland availability or proximity to woodlands. Fuel wood use surveys in the Basho valley of Pakistan (Ali and Benjaminsen 2004) and in rural Anatolia (Türker and Kaygusuz 2001) also demonstrate that per capita fuel use correlates positively with proximity to woodland resources. A general point arising from ethnographic and forestry management surveys from various world regions is that, when faced with wood fuel scarcity, communities often take steps to conserve limited resources. Similarly, when technological limitations (such as harvesting tools) or storage space are an issue, communities develop strategies to deal with such issues. Communities inhabiting the Yukon riverine areas (arctic Canada) reportedly ‘produce’ deadwood by peeling the bark from standing spruce trees, which leads to the tree slowly dying and being ready to harvest as standing dead trees in 4-5 years (Alix and Brewster 2004). Similar practices have been reported by Henry et al. (2009) from Siberia. Such strategies not only imply long-term planning to guarantee the availability of dry firewood, but also suggest that these communities took steps to incorporate woodland management and fuel harvesting practices into their mobile lifeways, by literally *storing* wood in its natural habitat until it is light enough to transport easily and dry enough to be used as fuel without the need for seasoning.

Some of the narratives on deforestation and over-exploitation of forest resources stem from romanticised views of the ‘pristine forest’ or the ‘uninhabited wilderness’. Often, when such areas of wilderness exist within the territory of a settlement they are believed to be inhabited by spirits, as is the case with the rainforest (*afán*) in the cosmology of the Fang discussed earlier (Picornell et al. 2011). A similar worldview is reported from Rajasthan, India (Gold and Gujar 1989) where specific areas or even individual trees are associated with deities and therefore are not harvested. In some cases, even deadwood collection may be prohibited, reinforced by mythical stories and oral traditions. In these areas there is a deeply rooted desire to preserve environmental conditions to please the deities. Similar ‘sacred groves’ with high biodiversity, which is often enhanced by deliberate planting, are reported from other locales in India (Gadgil and Vartak 1976, Asouti and Fuller 2008).

In many cases, the need for fuel wood is supplemented by waste from crop processing, dung, defunct timber, etc. In northern Iraq historically large oak trunks were preferred for the manufacture of posts and beams to be used in building construction. Since these mature trees, especially when used without the removal of sapwood, are susceptible to heart rot, old timbers are removed from the houses and burned as fuel (Chapman 1948). Dung cakes are used throughout Southwest Asia, often in outdoor fires, as fuel wood supplements alongside crop processing waste such as cereal dehusking waste, straw and stalks (Miller 1984, Barnard 1985, Reddy 1999). Crop processing waste is preferred as tinder because it flares up quickly and dies out without leaving embers (Barnard 1985). There is a vast amount of literature on the use of dung as fuel, and (as noted already) it is often interpreted as being used in conditions of wood fuel scarcity (cf. Bottema 1984, Miller 1984, Anderson and Ertuğ-Yaraş 1998, Reddy 1999). Dung fuel is rarely reported as being used in indoor fires for heating since it produces a lot of smoke; even when it is used (including outdoor fires) it is frequently supplemented with wood (Meyer 2003, Zapata et al. 2003, Shahack-Gross et al. 2004). However, in some cases dung fuel is preferred as it provides advantages associated with particular tasks or with use in specific fire features (Winterhalder et al. 1974, Barnard 1985, Hastorf and Wright 1998, Sillar 2000). For example, while communities in the Moroccan Rif rarely use dung fuel for indoor heating, dung is preferentially used for firing pottery in large outdoor fires (Zapata et al. 2003, Peña-Chocarro et al. 2005). A similar preference for the use of dung fuel in outdoor pottery firing is reported from communities in the Andes (Sillar 2000). This author reports that using a modest amount of wood fuel on the base of a shallow outdoor firing pit the potters arrange the wares on top, interspersed with dung cakes, and create a dung-lined dome above them. During firing, the quantities of ash produced by the dung cakes insulate the pots thus creating a more stable temperature inside the dome (Sillar 2000). Observations of outdoor oven (*tandır*) and cooking installation use in Uzbekistan reveal that in some cases when dung fuel is used alongside wood the fire could last longer and provide similar, albeit more stable, temperature ranges compared to wood fuel (Gur-Arieh et al. 2013).

In sum, fuel selection (or more correctly procurement) cannot be considered as predominantly functional, cultural, or technologically and environmentally optimal. From an anthropological perspective, all such considerations (and perhaps several more not necessarily amenable to direct empirical investigation) contribute to the decision-making strategies of individuals and social groups about how, when, where and which fuels to use for a wide range of purposes. In the end, what we find in the archaeological record are the material residues of fuel procurement and consumption representing the end product of complex *chaînes opératoires* of fuel use (Dufraisse et al. 2007, Dufraisse 2012). As a result, anthracological assemblages, along with the residues of other fuel types, reflect not only the vegetation accessible to (and used by) the communities in a given settlement, but also the ways in which such resources were perceived, adapted to local conditions and technologies, and finally incorporated into daily life. The question thus remains as to whether wood charcoal macro-remains provide suitable datasets for inferring past vegetation. It would seem reasonable to argue that (as demonstrated by the review of the taphonomic processes affecting fuel wood debris including carbonisation, depositional and post-depositional processes) anthracological remains may provide (depending on the application of appropriate sampling and analysis protocols reviewed in section 4.3) a representative picture of long-term fuel wood use by past societies. In addition, as the review of the available anthropological and ethnoarchaeological literature on fuel use suggests, fuel wood selection is constrained by the prevailing environmental and socioeconomic conditions. Therefore its empirical investigation may provide insights not only into the composition and ecology of the vegetation catchments used by prehistoric communities, but also into their attitudes towards, and perceptions of, the environments they inhabited. Furthermore, as mentioned earlier in this section, the environmental availability of desired fuelwood species (and/or deadwood) is constantly monitored, maintained and modified by various groups. Short-term shifts in preferred fuel wood taxa thus reflect changes in the perceptions and use values of different species of fuelwood. Conversely, long-term shifts in fuelwood use, and species preference, are not only shaped by changes in ecological conditions by also major changes in people's woodland management and use strategies.

4.3 Overview of sampling, qualitative and quantitative anthracological methods

4.3.1 Field sampling and recovery of wood charcoal macro-remains

Since the late 1960s water-assisted recovery techniques (flotation) have been the most common method of retrieval of carbonised plant macroremains from archaeological sites (Struever 1968, Helbaek 1969, French 1971). Flotation is a technique that separates plant material from the rest of the soil matrix using the differences in the densities of organic and inorganic material that allow for the less dense plant material to float while the denser mineral fraction sinks (Wagner 1988, Pearsall 2000: 62). To assist and speed up the disaggregation of plant remains from the soil, manual or mechanical agitation is used in various flotation systems. Of the mechanized flotation systems, perhaps the most commonly used in Southwest Asia (and also the system used at Çatalhöyük, Boncuklu and Pınarbaşı) consists of a 200 litre main tank, directing a steady flow of water into the tank with a water hose attached to the side that aids the separation of light organic materials from heavy residues. This system is also often combined with two larger settling tanks, and with the use of a motor pump which is used to recycle water. It is noted that in a comparison of various techniques for the retrieval of charred plant materials, the rates of recovery of remains achieved by this method of flotation are extremely high (averaging to about 89% of the total sample in tests carried out) (Pearsall 2000: 82).

The collection of dry-sieved materials without the use of water separation tends to overlook those plant remains that are smaller than the screen size used for sorting sediment on site, and reflects a bias towards the higher recovery rates of larger plant remains visible with naked eye such as corn cobs (Pearsall 2000: 83). Similarly, water sieving (the screening of sediment with the help of a water hose where the matrix is washed away through the screen), provides a crude method of recovery for more fragile plant materials (Pearsall 2000: 80). Flotation of sediments in small quantities may also be carried out without the use of a high pressure water source where the water agitation is provided manually by stirring or shifting the soil held in a mesh insert (also referred to as bucket flotation). This technique can provide a high recovery rate, at times higher than machine-assisted flotation, but is labour intensive and unproductive with sample sizes larger than a few litres (Riehl 1999: 16).

Referring specifically to wood charcoal macro-remains, when fragments are manually collected this leads to a biased picture of sample composition, as it tends to favour the recovery of the largest fragments (Keepax 1988: 43, Chabal et al. 1999). One situation in which hand-picking is preferable is when sampling burnt structural timber remains; in order to retain the integrity of individual specimens for recording grain orientation and placement of timbers, studying tool marks, or for dating purposes (i.e., dendrochronology and radiocarbon dating) (Asouti 2002: 97). Another is when visible remains of artefactual wood are preserved, or when sampling the in situ remains of burnt embers inside hearths that may contain valuable information regarding the size and calibre of the wood used as fuel (Asouti 2013).

Some authors have expressed concern regarding taxon representativeness and the rates of wood charcoal recovery when water-recovery is used (e.g., Keepax 1988: 70-79, Brady 1989, Greenlee 1992). It has been suggested that wood charcoal specimens can be subject to further fragmentation during flotation as a result of wetting and drying of charcoal particles (Keepax 1988: 76, Brady 1989: 210). In extremely dry conditions, especially when specimens are desiccated, contact with water during flotation can result in further damage to plant remains, regardless of size, and may lead to fragmentation (Pearsall 2000: 80-83). Pearsall also notes that, especially in extremely arid soils, where plant remains are not exposed to wetting-drying cycles, flotation could cause the wood charcoal specimens to "explode" which might produce an abundance of very small fragments (<1mm) (Pearsall 2000: 82). In such instances, using a system of dry-sieving (with 2mm, 1mm and 0.5mm meshes) is recommended, although this is a time consuming undertaking. Experiments by Brady (1989) on modern charred wood showed no significant loss of wood mass or fragment size when processed with flotation. Experiments by Greenlee (1992) on random sub-sets of archaeological soils (four 1-litre and two 0.25 litre sub-samples of the same context) indicated slight differences in the number of larger fragments as a result of different processing techniques. The author notes that flotation results in a small increase in the number of <1.5mm fragments and a parallel reduction in the number of >6mm fragments. Even though the experimental sample size was rather small, Greenlee (1992) observed more significant differences in the weights of size classes recovered through different processing methods. More recent experiments suggest that both dry-sieving and flotation have an impact on the composition of wood charcoal assemblages from archaeological sites, by producing a higher number of smaller fragments (Théry-Parisot et al. 2010a). Yet, when the distributions of weights and fragment numbers (corresponding to different size fractions: >4mm, >2mm, >1mm) are compared, the resulting assemblages indicate similar distributions. Therefore, Théry-Parisot et al. (2010a) argue that either method of field processing will result in equally representative sub-samples of the wood charcoal assemblages.

Due to the amount of time and labour required for the processing of sediment from sites, a sampling strategy is often employed. Total sampling (also referred to as blanket sampling) describes the situation whereby systematically chosen samples are taken in equal amounts from each context. This may be impractical at large excavations due to the amount of work involved in sample processing. More commonly, samples are chosen based on previous knowledge or expectations (judgmental or purposive sampling). In this case certain contexts known to yield botanical remains are targeted for sampling (e.g., fire installations, pits, middens, etc.) Another approach is probabilistic sampling, where only randomly chosen contexts are sampled (Toll 1988, Pearsall 2000: 69). Of the mentioned sampling techniques, blanket sampling is the ideal, whereas purposive or probabilistic sampling strategies may produce more manageable sample volumes. One downside of focusing on specific context types such as hearth features or pits is that such a sampling strategy may result in a partial and biased archaeobotanical record reflecting contexts associated with particular types of activities (Dennell 1976: 230). As Toll (1988) argues, contexts carrying low densities of charred plant remains may also add to our understanding of taphonomic patterning in macro-botanical datasets, and are therefore very important for studying formation processes. In certain situations 100% processing of all excavated deposits through flotation is applied; the Epipalaeolithic and aceramic Neolithic sites at Pınarbaşı are a typical example, whereby such a sampling strategy was employed due to the very low densities of plant remains recovered from these early sites (Baird pers. comm.)

4.3.2 Quantitative and qualitative methods of analysis in anthracology

4.3.2.1 Sampling and subsampling

Since, from a taphonomic point of view, context type represents an important factor in charcoal preservation and fragmentation, contextual information is critical for sample selection. For instance, contextual information provides the interpretative background with which to decide whether wood charcoal fragments from a particular sample are likely to represent the remains of fuel (domestic or otherwise) or timber. Not all deposits have the same interpretative potential for addressing questions relating to wood fuel and timber use, the environment and past vegetation (see also Table 4.1). Close examination of the excavation records and other eco-factual data (e.g., animal bone, seeds, etc.) from each sampled location is necessary in order to infer on the function and provenance of contexts (Chabal et al 1999: 61). Equally important is the duration of the activities represented in the archaeological record. From a fuel use perspective, short-lived contexts and/or primary deposition contexts (e.g. hearths, fire spots) tend to hold in situ burnt refuse. Wood charcoal fragments found in these contexts are likely to represent the remains of their last use, which may be heavily impacted by diverse post-depositional processes. Therefore they are not suitable for reconstructing long-term patterns of fuel use. Such contexts provide a unique snapshot of fuel use and hold great potential for understanding the different combinations of fuel types used and how these varied depending on different activities (e.g. cooking, pottery firing, etc.) as they often contain traces of waste material indicative of the main use of such features. In some instances a substantial quantity of charcoal is retrieved from fire features which may contain a diverse range of taxa. However, it is highly likely that such a composition is more related to the specific circumstances of the last firing event and does not represent a long-term trend in woodland availability or changes in vegetation cover. Similarly, in situ burnt timbers and building collapse debris provide invaluable evidence on the choice of building materials and their preparation, in addition to cultural preferences relating to architectural styles (Asouti 2013).

On the other hand, deposits accumulated in the long-term (e.g., midden layers, building infill and other dispersed contexts, '*charbon de bois dispersés*' Chabal 1992, Chabal et al. 1999) are likely to contain charred fuel refuse from multiple episodes of discard. However, the degree of preservation of such deposits depends on the duration of surface weathering, trampling, and the frequency and regularity of disposal events.

For instance, daily cleaning and disposal of fuel waste would be expected to result in a mostly homogenous accumulation of year round fuel use, reflecting long-term fuel preferences and consumption patterns. Another important aspect is the spatial pattern and representativeness of the middens sampled, as it is possible that contemporary buildings or 'neighbourhoods' might have had slightly different patterns and preferences of fuel wood use. At the same time, such deposits are much better suited to reflect lasting patterns of firewood selection and consumption. They are also likely to produce a high diversity of woody taxa and may therefore maximise the potential of the anthracological work for reconstructing past vegetation.

Sub-sampling methods are frequently used in archaeobotanical studies in order to maximise the amount of information gained from the time consuming analysis of large assemblages (e.g., van der Veen and Fieller 1982, Pearsall 2000). In anthracology, sub-sampling allows for the examination of a higher number of sampled contexts per stratigraphic level, thus enabling the more reliable reconstruction of the diversity of species used as fuel and its changes through time. The principles behind the most commonly applied sub-sampling strategies have been established by Chabal (1991, 1992, 1997) and Chabal et al. (1999). As already discussed, wood charcoal fragmentation follows a general pattern, resulting in a low number of large fragments and a high number of small fragments, with fractions >2mm being the most representative with regard to taxon presence. Therefore an examination of a representative subset of the >4mm fraction from each sampled context (or >2mm when >4mm fragments are not available) is likely to produce a dataset reflecting the relative proportions of wood charcoals deposited in that context. The minimum number of specimens identified (i.e., the optimal sub-sample size) is determined for each sample using a taxon diversity saturation curve (see Fig. 4.4). According to Chabal et al. (1999) and several other anthracological studies (e.g., Keepax 1988, Badal-Garcia 1992, Asouti 2002, 2005, Asouti and Austin 2005) a greater proportion of taxa are identified in the first few specimens identified. After a certain point (approximately the first quarter of the optimal sub-sample size) newly identified taxa become fewer and less frequent. The cumulative distribution of diversity follows an exponential curve as illustrated in Fig. 4.4. The optimal size of the sub-sample is determined when no new taxa are identified (i.e., the curve levels off).

4.3.2.2 Qualitative and quantitative methods of wood calibre estimation

Estimates and measurements of wood growth ring diameter (minimum diameter of wood harvested) have been applied in anthracology in a variety of ways since the 1970s (Willerding 1971) and developed further by other researchers later (Hillebrecht 1982, Marguerie 1992, Marguerie and Hunot 2007, Ludemann and Nelle 2002, Dufraisse 2002, 2006, García Martínez and Dufraisse 2012, Paradis et al. 2013). As mentioned in the previous section, the size of wood collected as fuel is often more important as a selective criterion than species availability. Therefore a considerable amount of emphasis has been placed on improving wood calibre measurement and estimation methodologies over the last two decades. There are two main approaches currently employed in anthracology: (1) qualitative estimation of ring curvature, and (2) quantitative calculation based on growth ring curvature and ray angles.

The ring curvature estimation criteria developed by Marguerie (1992) and Marguerie and Hunot (2007) classify growth rings into three groups (Fig. 4.5): Curvature Degree (CD) 1: weakly curved rings; CD 2: moderately curved rings; and CD 3: strongly curved rings. The definition of curvature classes is based on the observation that small branches and twigs have strongly curved growth rings while moderately large trunks have CD 2 and large trunks have CD 1 growth rings. This methodology has been criticised as insufficient since curvature degree determination is done based on arbitrarily set classifications (Paradis et al. 2013). However, as it can be performed speedily and concurrently with botanical identifications, it provides an expedient tool for assessing overarching trends in wood fuel use.

Quantitative methods of calibre measurements made using a transparency printed with growth ring perimeters of different diameter classes provides a visual estimate of growth ring morphology (cf. Willerding 1971, Lundström-Baudais 1986, Ludemann and Nelle 2002, Dufraisse 2002, 2006). Another variant of this approach is the use of the “circle tool” in microscope imaging software in order to provide a good fit of a circle or arc on the largest visible growth ring of a specimen (Ludemann 2006; see also Fig. 4.6). Both methods have been criticised for being affected by variations in growth ring morphology such as wavy growth rings resulting from climatic or mechanical stress during tree growth. Paradis et al. (2010, 2013) have reported on the results of a new method of measuring wood calibre (the “trigonometric tool”) using the angle of the rays along with the growth ring boundary in order to provide a more accurate estimate of minimum wood diameter from the surviving charcoal fragments. For each radius of curvature measurement, three parameters identifiable on wood are estimated: the radius of curvature which corresponds to the distance between the last visible ring and the pith of the wood, the angle between two wood rays, and the distance between two wood rays (Fig. 4.7). Their calculations rely predominantly on the measurements of two rays on the transverse section, as a result of which an estimate for the degree of the triangle (in-between the two rays) can be used, along with the widest distance between the two rays, to estimate the full extent of the radius of a given fragment of wood (see Fig. 4.7). These authors have also conducted experiments on wood of known diameter (both freshly cut and carbonised) to test the reliability of various techniques of wood calibre estimations, comparing trigonometric estimation methods with the circle tool (Paradis et al. 2013). They report that measurements made using the circle tool produce a much larger error (nearly 1/3 of the measurements producing >60% error) because they aim to calculate the perimeter of the original log rather than its diameter. Other techniques which rely on geometric and/or trigonometric measurements using the angle of the rays and the distance between two rays to calculate the radius of curvature (see Fig. 4.7) produce a much lower margin of error, since a number of anchor points are used that can account for variability in curvature. The authors note, however, that it is often difficult to make accurate diameter measurements of twigs (≤1cm in diameter) due to the acute angle of the rays close to the pith (Paradis et al. 2013).

It should be emphasised here that none of the above mentioned studies of wood calibre and diameter have included experimental analyses of the relationship between these properties in unburnt wood and fuel waste debris. Therefore, fuel waste remains have not been formally assessed with regard to how representative they might be of the size and calibre of wood originally put into fires. Dufraisse (2008: 203) has proposed on theoretical grounds that fuel waste debris comprises wood charcoal fragments reflecting the calibre of the logs originally put into fires. Furthermore, she argues that the majority of the preserved fragments will derive from the largest diameter portions of the logs originally put into fire. For example, she has suggested that a log of 15cm diameter will result in wood charcoal fragments a majority of which when measured with the trigonometric tool will produce diameter estimates approximating 10-15cm (see Figure 4.8). This proposition is assessed in the present study by examining the distribution of estimated diameter size classes. Both qualitative and quantitative methods of wood calibre estimation have been used for fragments >4mm from the Çatalhöyük anthracological assemblage (materials from the other sites contained very few >4mm fragments to permit the systematic application of these methodologies). The rationale and specifics of the methodologies applied (including statistical analyses of the resulting data) are detailed in Chapter 5, sections 5.1.1 and 5.1.2.

4.3.2.3 Recording of dendroecological features

Other than taxon presence, fragment counts and calibre estimations a host of other anatomical features were recorded relating to the dendroecological attributes (i.e., growth conditions/stress and woodland management) of the taxa retrieved from the anthracological assemblages studied in the present thesis (for details, including methods of quantifying the presence of such features, see Chapter 5). These are summarised below and include the presence of deadwood, tyloses, compression/tension wood, callus tissue and radial overgrowth, recurrence of abnormally narrow growth rings, and collapsed vessels/tracheids and broadleaf wood grain tissue (fibres).

As described earlier in this chapter, wood is subject to decay as a result of fungal, bacterial and insect attack leading to the decomposition of woody tissue, which leaves behind certain signs of degradation (Blanchette 2000, Schweingruber 2007). Fungal hyphae and mycelia can be identified during microscopic observation of the specimens (cf. Marguerie and Hunot 2007, Moskal-del Hoyo et al. 2010; see also Fig. 4.9). In addition, insect boreholes and some types of bacterial degradation can also be observed. The detection of fungal hyphae enables the identification of deadwood used as fuel, either collected from woodlands or derived from burnt timber fragments that may have been exposed to heart-rot prior to burning. Recent ethnoarchaeological studies by Henry and Théry-Parisot (2014) suggest that in addition to the presence of fungal mycelia and insect boreholes, wood that has been subject to severe degradation (e.g., rotting) may also display collapsed vessels (hardwoods) and tracheids (gymnosperms). These authors also note that in some cases the degradation is so severe that it leads to a partially lignified cellular structure on the transverse section that may even render the specimen unidentifiable.

Tyloses are overgrown parenchyma cells which spread through pitting on vessels filling out the vessel cavity (Fig. 4.9). They develop as rounded to bladder-like thin-walled extensions of the parenchyma cells adjacent to the vessels; as tyloses become larger they press against the vessel walls and become compressed forming prismatic structures inside the vessel (Wilson and White 1986: 207-211, Taylor et al. 2002). In some cases groups of tyloses may become lignified and block the vessel completely, leading to lower permeability of heartwood and thus increasing the resistivity of wood to the spread of fungal hyphae (ibid). Some hardwood species do not produce tyloses regularly, but might do so under conditions of stress or trauma. Since tyloses are usually absent from sapwood (the outer part of the wood tissue closest to the bark) recording of their presence provides a measure of which part of the tree is most commonly present in the charcoal assemblage, and whether stems might have been stripped off their bark and sapwood prior to being used as fuel wood or timber. The transition zone from sapwood to heartwood is reportedly brief, represented by 1-2 growth rings (Wilson and White 1986: 208) in which case tyloses, if present, might be poorly formed or hard to recognise. However, if trees are felled during their active growth season then tyloses may develop in the sapwood as well. Tyloses may also form when wood is cut during dormancy and then stored for a period of time, and in the transition between heartwood and sapwood, or as a result of other kinds of physical injury (trauma) (Murmanis 1975, Schweingruber 2007). Sapwood may also be completely consumed by fire (depending on hearth type and function), in which case a majority of the fragments exhibiting tyloses are likely to have derived from heartwood.

More specific insights on the ecology of the trees harvested for fuel and timber may be provided by the presence of tension and compression wood (see also Fig. 4.9). Under intense mechanical stress (e.g., wind exposure) conifers will form compression wood while hardwoods tend to form tension wood during growth (Timell 1986, Schweingruber 2007: 127-137). Eccentricity of growth rings and the formation of reaction wood are specifically related to mechanical stress. Open wounds (e.g., from bark stripping) cause increased cell formation and cell wall thickening, as well as a change in fibre direction, resulting in scar tissue (Figure 4.10). Callus tissue formation and radial overgrowth were also recorded (as outlined in Schweingruber 2007: 139-178) alongside other indicators of cutting and debarking followed by re-growth and recovery of the tree. Callus formation can be caused by numerous factors including various scars to the bark and the cambium caused by lightning, fire, bark stripping, frost and hail damage, the shedding of twigs and/or needles, etc. (Schweingruber 2007: 188) (Fig. 4.10). Traumatic resin canals in conifers and traumatic gum ducts in angiosperms (hardwoods/broadleaves) can be also be formed in response to a number of factors including spring frost and other extreme weather conditions, and defoliation by insects (Fig. 4.11) (Schweingruber 2007: 85, 182, 187).

It is often difficult to differentiate between the impacts of woodland management strategies, such as coppicing, pollarding, lopping etc., and environmental parameters on wood anatomy, as several ecological and anthropogenic factors impact on the growth conditions of managed or unmanaged stands. This situation is further accentuated by the vast amount of intra-specific variability that exists in the wood anatomical characteristics of seedlings, shoots (long and short) and stems (see also Fig. 4.12). Various studies of managed woodlands (e.g., Peterken 1993, Rozas 2003, 2004, Corcuera et al. 2006, Copini et al. 2010, Altman et al. 2013, Deforce and Haneca 2014, Gebhardta et al. 2014) have shown that management strategies impact on wood anatomy either by enhancing or hindering radial growth (hence growth ring width). Coppicing is one of the most common methods of woodland management for the purpose of fuel wood harvesting and often involves mixtures of coppice stools and large, mature trees (standards). Generally, shoots growing from cut down coppice stools have larger vessel diameter and wider growth rings compared to seedlings (see Figures 4.12 and 4.13). After a cycle of thinning, involving either a cycle of cutting down a patch of coppice stools or the thinning of standards, the remaining trees experience improved growth conditions with an abrupt increase in ring width, also referred to as growth release periods (Schweingruber et al. 1990, Corcuera et al. 2006, Altman et al. 2013, Schweingruber 2007; see also Fig. 4.13). This improved growth potential, or growth release, is sustained for a number of years (5-10 years) and ring width remains substantially higher than average growth years. In the years leading up to a cycle of cutting, a great majority of the sprouts and stems on coppice stools display reduced growth rates, due to competition for light and nutrients induced by increased canopy density, a period described as growth suppression (see Fig. 4.13, Schweingruber et al. 1990, Rozas 2004, Bleicher 2014). On the other hand pollarding, pruning and browsing result in a sudden reduction in growth rate, due to trauma and subsequent radial overgrowth (Thiébault 2006, Schweingruber 2007: 139; see also Fig. 4.14).

Characteristic wood anatomical features include series of successive very narrow growth rings, missing or false rings, callus and scar tissue, radial overgrowth, collapsed fibres/tracheids and traumatic canals/gums.

While the impacts of silvicultural practices described above tend to last for a number of years after the occurrence of wood cutting, tree responses to extreme environmental conditions such as spring frost or spring/summer drought are usually limited in the year of growth immediately following the event. If drought events are seasonal in nature, their impacts are limited to the formation of the early wood (see Fig. 4.15). Extreme climatic events occurring at much longer intervals may result in the formation of distinct growth anomalies for a cycle of 1-2 years. For instance, severe drought occurring on a decadal scale during the growth season will result in the formation of 1-2 very narrow growth rings that may display a number of irregular anatomic features. Therefore, the impacts of climatic events on growth ring width and anatomy are of limited duration compared to the impacts of silvicultural practices and herbivore browsing.

4.4 Summary

As outlined in the detailed discussion of the taphonomic processes affecting wood fuel including collection, burning, cleaning of fire features, discard and weathering, the proportions of different species used in individual fire events and also long-term signatures of dominantly used fuel taxa can be reconstructed through anthracological analyses. Careful consideration of the context types targeted for analysis, and of sampling and sub-sampling protocols, enables closer control over the reliability of the results of anthracological research. Fuel wood preference is shaped by both socio-cultural and environmental variables, and ease of collection (e.g., deadwood) and is not necessarily tied to taxon-specific wood fuel properties. Socio-economic and palaeoenvironmental interpretations of anthracological assemblages must be evaluated against temporal variations in intra- and inter-site assemblage composition, cross-checked with existing off-site palaeoecological and palaeoclimatic records and further investigated for coherence in deposits accumulated in the long-term (i.e. dispersed contexts, *'charbon de bois dispersés'* Chabal 1992, Chabal et al. 1999). Anthracological remains of wood fuel use, particularly in semi-arid inland Southwest

Asia where insect-pollinated woodland taxa form important elements of woodland vegetation, provide valuable insights to woodland composition and vegetation dynamics in prehistory alongside other palaeoecological proxy datasets. Short-term and long-term changes in fuel wood use are likely to represent different dynamics of shifts in the environmental availability of particular species, the management of woodland resources and in socio-economic decision-making. Therefore, detailed studies of fuel wood use, including dendroecology and calibre estimations, provide further insights into local and regional woodland ecologies and the conditions of growth of collected wood fuel taxa. In the next chapter, first the specific analytical methods, and sampling and sub-sampling protocols employed in the present study are described. Then, the results of the anthracological analyses from each site are presented followed by the results of multivariate statistical analyses conducted on charcoal taxon counts, dendroecological features and dung-derived non-crop seeds and faunal datasets.

CHAPTER 5: PRESENTATION OF ANTHRACOLOGICAL METHODS, RESULTS AND STATISTICAL ANALYSES

5.1 Methods applied in the present study

5.1.1 Sample provenance, selection, sub-sampling and anthracological analysis methods

Soil sampling for flotation, carried out as part of the routine excavation program at Boncuklu and Pınarbaşı included sampling each excavated context at 100%. This strategy had been applied without exceptions at Pınarbaşı, due to the low density of plant remains. At Boncuklu, for large contexts, providing more than 60 litres of soil, 50% was kept for water sieving, while the remaining 50% was processed through flotation. On-site sampling and flotation at Çatalhöyük involved all excavated contexts, with at least 40 litres of bulk soil processed for flotation from each unit, when available.

In order to address research questions pertaining to the preferences and use patterns of different types of fuel through time, all available anthracological remains from *in situ* fire features were selected and examined fully in the present study. In addition, a range of dispersed contexts (e.g., middens, building infills; '*charbon de bois dispersés*' cf. Chabal 1992, Chabal et al. 1999) were selected, with the aim of producing a representative sequence covering all phases of occupation at each site. Charcoal specimens from each flotation sample (archaeological unit/context) were analysed employing the sub-sampling strategy described by Chabal et al. 1999 (see also Chapter 4 and discussion below). Following the application of a rarefaction curve, taxon diversity and density curves were recorded in order to deduce the number of specimens identified in each sample. In diverse units the total number of identified fragments was taken up to 150. This sub-sampling protocol builds on previously completed work on wood charcoal macroremains from Çatalhöyük (Asouti and Hather 2001, Asouti 2002, 2005, 2013) and Pınarbaşı (Asouti and Hather 2001, Asouti 2003a).

All examined wood charcoal fragments were obtained from the >4mm and >2mm fractions of the dry-sieved flot samples. At Çatalhöyük sub-sampling focused on the >4mm fraction; at Boncuklu, Pınarbaşı and Can Hasan III the absence or very low proportions of fragments >4mm necessitated focusing on the >2mm fraction. Charcoal flot fractions from each sample were weighed using a three decimal point, digital scale. Charcoal fragments were sorted with the aid of a GXMMZS0745TL-R Zoom stereomicroscope. Depending on their size, wood charcoal specimens were either hand- or pressure-fractured with a carbon steel razor blade in order to produce a fresh section in all three anatomical planes (transverse, radial longitudinal and tangential). Each section was examined under a high power, epi-illuminating brightfield/darkfield Brunel ICM 110M metallurgical microscope at magnifications of x50, xl00, x200, x400 and x500. Scanning Electron Microscope imaging was applied to select specimens using a Hitachi TM3000 Benchtop SEM (see Figures 5.1-5.13, 5.15, 5.17, 5.19-5.21, 5.24-5.29). Botanical identifications (to species, genus or family level) were made by using various identification manuals, dichotomous wood anatomy keys and wood anatomical descriptions of specimens from Southwest Asia and Europe (Western 1969, Fahn et al. 1986, Schweingruber 1990, Greguss 1955, 1959, Akkemik and Yaman 2012, Crivallero and Schweingruber 2013). In addition, carbonised remains were compared to the modern wood reference charcoal and thin sections slide collections housed in the Archaeobotany Laboratory of the University of Liverpool, plus wood anatomy online databases (‘Inside Wood’; Western A.C. ‘Wood Anatomy Notebooks’). Descriptions of all identified taxa have been included in Appendix A.

The identifications of wood charcoal specimens from each sample were recorded using a standardised recording system; each recorded fragment was given a specific identifier number in the order in which it was counted. This procedure enabled the calculation of taxa diversity saturation curves for each analysed flot fraction, thus determining sub-sample sizes for units with numerous charcoal particles as proposed by Chabal et al. 1999 (see also discussion in Chapter 4).

Identification of dendroecological features can be reliably carried out only on charcoal particles >4mm. At Pınarbaşı, Boncuklu and Can Hasan III, the majority of the examined fragments were ~2mm in size. Therefore they did not provide a large enough observation surface on the transverse plane for detailed and precise dendroecological analyses. For this reason, dendroecological methods were only applied to the Çatalhöyük anthracological assemblage. For all examined specimens in the Çatalhöyük dataset the presence/absence of the following features was recorded: tyloses, fungal hyphae, resin canals, gum ducts, callus/scar tissue, boreholes, collapsed vessels or tracheids, narrow growth rings, false growth rings, tension wood, radial cracks and mineral deposits (see Fig. 4.9; for examples of these features in the anthracological specimens see Figures 5.1-5.20). In addition, where possible, the Marguerie and Hunot (2007) technique of growth ring curvature classification (Curvature Degree 1: weakly curved rings, 2: moderately curved rings, 3: strongly curved rings) was also applied (see Chapter 4, Fig. 4.5). While this technique provided an expedient estimation of wood calibre ranges, a more precise measurement methodology (the “trigonometric tool”) was also applied to select specimens of particular taxa from each sampled unit in order to provide more accurate estimations of wood calibre ranges. For this, up to 10 fragments (>4mm) comprising ring-porous taxa (*Quercus*, *Celtis*, *Ulmus* and *Fraxinus*) were selected from each sample for estimating wood diameter ranges. As already discussed in Chapter 4, diameter estimation techniques such as the circle tool, which rely only on the detection of the growth ring boundary, result in a very large margin of error and thus grossly over-estimate diameter size classes. On the other hand, the more precise techniques relying on trigonometric measurements of the growth rings require the visibility of a larger transverse plane on each specimen, plus visible early wood pores and visible (i.e., thick and long) rays. Therefore, at Çatalhöyük, such measurements could only be applied to the four taxa listed above. Transverse sections of specimens preserving at least 3 growth rings and 2 clearly visible rays were photographed using a 5-megapixel GXCAM-5 digital colour camera attached to the zoom stereomicroscope at magnifications x7-x45. Diameter calculations were produced using the GXCapture 7 software following the trigonometric tool diameter estimation techniques and protocols described by Paradis et al. (2010, 2013). Paradis et al. (2013) implement this measurement technique by measuring the distance between the two most distal rays that are visible on the specimen, and measuring the angle between the two rays. In the present study a modified version of the “trigonometric tool” (as developed by Paradis et al. 2013) was applied. The distance between the two most distal rays that are visible on the specimen was also measured. However, in order to calculate the angle between them, the angle between one distal ray and the straight line connecting the two distal rays was measured; this value was then subtracted from 90° thus calculating 1/2 of the angle between the two rays (see also Fig. 5.30; detailed examples of actual anthracological specimens that were studied with this measurement protocol are presented in Figures 5.31, 5.34).

5.1.2 Quantification and statistical analysis methods

Density of plant remains and taxonomic diversity are widely used by archaeobotanists and anthracologists to evaluate changes in the charred plant macro-remain assemblages when comparing samples from different contexts, or the rates of accumulation of charred plant remains at a site through time (Pearsall 2000). Density is generally expressed as either the number or the total weight of charred items per litre of floated sediment, and diversity as the number of species/taxa identified from each context/stratigraphic phase or site. In order to assess taxon distribution patterns and the representativeness of the sampled units, the charcoal weights of the flot fractions >4mm (for the Çatalhöyük samples) and >4mm, >2mm (for the Pınarbaşı, Boncuklu and Can Hasan III samples) were used to calculate density (expressed as g/litre of floated sediment). Density distributions were assessed and evaluated with regard to their representativeness for different context types using non-parametric techniques (histograms).

For each unit/context the number of fragments identified from each taxon was counted, in addition to counts of indeterminate fragments and taxa identified with some level of uncertainty (e.g. identified as cf. 'possible identity'). Units from dispersed deposits ('*charbon de bois dispersés*' cf. Chabal 1992, Chabal et al. 1999) were organised according to stratigraphic phasing; the total fragment counts of each taxon were converted to percentage fragment counts, which were calculated on the basis of the total number of identified charcoal fragments (after excluding indeterminate fragment counts and cf. identifications from the charcoal sums). Per-phase percentage fragment counts were used to produce anthracological diagrams using the R statistical software (version 3.1.1, package 'rioja', function 'strat.plot'). Taxon ubiquity (the percentage of samples in which each taxon was present) also complements the detection of temporal patterning and between-sample (context-related) variation. A separate diversity measure (such as the Shannon-Weiner method, see Krebs 1999: 444) was not employed for evaluating sample diversity. While such indices could provide further insights into the 'evenness' of taxon abundance as well as taxonomic diversity, their application in anthracology would be at odds with anthracological sub-sampling methodologies. More specifically, the problem lies in the fact that for any given anthracological sample, subsample size is determined by the species diversity saturation curve; for this reason, more diverse samples tend to have higher fragment counts. Therefore, in this study the number of different taxa present in each sample was used as a method for evaluating diversity rather than relying on diversity indices derived from modern ecological studies.

In order to address research questions regarding selection of wood of particular diameter as fuel, woodland management and use practices, diameter calculations and ring width measurements were assessed using parametric and non-parametric statistics for each taxon included in the analysis, and for each stratigraphic phase. The main aim was to assess the distribution of diameter size classes and ring width size classes, and their implications with regard to taphonomic processes and woodland management practices. Diameter measurements were assessed formally, testing for the goodness-of-fit (using Kolmogorov-Smirnov, Cramer-von Mises and Anderson-Darling tests) in determining the underlying distribution of the dataset. Ring width measurements were evaluated using non-parametric techniques (e.g., distribution and histograms). Furthermore, possible correlations between diameter size classes and ring width measurements were investigated by plotting minimum, maximum, average and median growth ring width values against diameter measurements of the same specimens.

A range of multivariate techniques were applied to wood charcoal taxon counts, in order to investigate temporal and contextual variation and patterning in the datasets. For these analyses only contexts containing >25 identified fragments were included, in order to limit redundancy and noise in the dataset. Only positive identifications (to genus, species or family level) were included (cf. identifications were excluded from the data matrix). Correspondence Analysis (CA) was applied to per-sample wood charcoal taxon counts from all sites. CA has been applied to various archaeological and archaeobotanical datasets (cf. Shennan 1997, Colledge 2001, Baxter 2003, Bogaard 2004) with the aim of detecting patterning in large and complex sample populations. As one of the most widely used ordination techniques, CA allows for a two dimensional evaluation of complex patterning in the dataset by means of geometric representation along two axes. To date, CA has not been widely applied to anthracological analyses, with the exception of its limited application in previous analyses of charcoal assemblages from central Anatolia (Asouti 2003a, 2005). In the present study, CA was applied on the taxon count matrix using R (version 3.1.1, packages ‘ca’ and ‘FactoMineR’). In the resulting plots, individuals (i.e. samples) close to the origin (the intersection of the two axes plotted) reflect minimal variability, thus *average* composition. Separation on either side of axis 1 or 2 reflects dissimilarity in the samples and variables (i.e., taxa) included in the matrix (see also Wildi 2013: 43-47). Tables of eigenvalues, inertia and cos2 values have accompanied the resulting biplots of the first two dimensions in order to assess the quality of the emerging patterns and assist their interpretation.

The dendroecological dataset from the Çatalhöyük assemblage was investigated using two different techniques in order to account for the nature of the dataset. Dendroecological features reflect qualitative variables: that is, the absence of a feature (e.g., tyloses) does not represent a numerical value=0 per se, but rather the classification of a given specimen under a different category. In other words, dendroecological features represent categorical variables, in contrast to taxon counts that represent continuous variables. For this reason dendrological features were analysed using Multiple Correspondence Analysis (MCA) and Multiple Factor Analysis (MFA) (using R, version 3.1.1, package 'FactoMineR'). MCA is an ordination technique similar to CA, albeit particularly suited to the analysis of multiple categorical variables, and results in a similar reduction of dimensions in a complex dataset (Greenacre and Pardo 2006). The dendroecological dataset was analysed using individual specimens as data points (with a unique identifier) in order to examine the co-occurrences of individual dendroecological features and taxa. In addition to examining the distribution of individuals, it is also possible to evaluate the relationships between categories and supplementary variables (e.g. phase, context type) in the resulting biplots of the MCA. These are interpreted similarly to the results of CA, by taking into account the 2-dimensional representation of individuals plus variables, eigenvalues, contribution to dimensions by categories, and $\cos^2$ values (Husson et al. 2011: 127-169). Multiple Factor Analysis (MFA) was applied to per-sample wood charcoal taxon counts, and per-sample counts of the presence of each dendroecological feature, comprising a data matrix of taxon composition and dendroecological features. The aim of this approach was to explore the main components of the samples with regard to the co-occurrences of taxon abundance and the qualitative attributes of specimens (i.e., presence of fungal hyphae, tyloses, etc.) MFA relies on principles similar to Principal Components Analysis (PCA) in ordination, yet it allows for distinct groups of variables to be evaluated separately (Bécue-Bertaut and Pagès 2008, Escofier and Pagès 2008). This permits the simultaneous evaluation of inertia in a dataset where a number of different observations have been made on the same individuals (i.e., samples/units). Thus its results remain unaffected by differences in the quantification of distinct groups of variables (Escofier and Pagès 2008: 149-205). The basis for the use of factor analysis is the reduction of dimensions (and number of variables) in a dataset; thus, the theoretical basis for using similar ordination techniques for analysing the dendroecological dataset is that it allows assessing co-variation between qualitative variables and charcoal taxa. The results are evaluated similarly to PCA, whereby a map of variables (factors) represented in 2-dimensional space, reflects the nature of the relationship between different sets of variables. The plot of variables (and groups of variables) signifies a perfect correlation between variables if the arrows representing them overlap. A perfectly inverse relationship between variables is inferred when the arrows of two variables are at a 180° angle (i.e., they form a straight line). No significant relationship is deduced when the angle between the two variables is at 90°. These geometric representations are interpreted by taking into account the correlation between the estimate and the original dataset, and the contribution of individual variables to dimensions. On the other hand, the plot of individuals in MFA is created with the geometric average of the positioning of individuals calculated independently from the different groups of variables. Thus, the position of each individual is placed in the geometric mean of its position calculated with variable group 1 and variable group 2. MFA also displays the relationship between the positioning of these separate individual plots (i.e., the partial points). It thus reduces the complexity of multiple datasets by allowing for the interpretation of patterning for any given individual (i.e., sample/unit) within more than one dataset in the same geometric space.

MFA was furthermore applied to the charcoal taxon counts dataset in order to explore wood fuel use in a more in-depth manner. As documented by previous archaeobotanical research, fuel use at Çatalhöyük also routinely involved animal dung (cf. Fairbairn et al. 2005, Bogaard et al. 2013, 2014a, Filipović 2014). Thus, samples for which both charcoal and dung-derived non-crop seed datasets were available (following the classification of dung taxa by Bogaard et al. 2013, 2014a, Filipović 2014; see also Table 5.1) were collated into a single data matrix consisting of counts of wood charcoal taxa and counts of dung-derived seed taxa. These were analysed as two separate groups using MFA. Finally, temporal patterns in fuel use practices (as assessed through the wood charcoal and dung-derived seed dataset) were compared to trends in the hunted and herded faunal remains (select taxa including caprines, equids, cervids and boar as identified by Russell and Martin 2005, Russell et al. 2013) using MFA. This heuristic assessment was carried out on per-phase sums for all charcoal, seed and faunal taxa (following the recent re-evaluation of site phasing by Hodder; see also Chapter 3: Table 3.8).

5.2 Results of quantitative anthracological analyses: taxon presence, abundance and charcoal densities

The descriptive results of anthracological analyses undertaken as part of the present study from all context types, at each site (and phase) are presented in this section.

5.2.1 Pınarbaşı

Samples from two occupation phases at Pınarbaşı were analysed for the present study. From the Epipalaeolithic occupation at Site B wood charcoal remains (>2mm) were preserved in 12 dispersed occupation and midden-like contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), while 1 primary fire feature contained identifiable wood charcoals (see also Table 5.2). Wood charcoal density was very low, with an average of 0.00128 g/l in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999). A total of 183 fragments from these contexts were identified to genus or family level while a further 56 fragments were classified as indeterminate due to their poor preservation and/or the absence of a sufficient number of anatomical features. *Amygdalus* was the dominant taxon by both frequency and ubiquity, represented with 95 fragments and present in 85% of the samples (see also Table 5.3). *Juniperus*, mostly in the form of twigs and small round wood, was the second most abundant and ubiquitous taxon, with 53 fragments present in 69% of the analysed samples. Maloideae and *Pistacia*, much lower in abundance, occurred in less than half of the samples (46% and 38% respectively). Fragments of *Celtis*, Salicaceae, *Fraxinus* and Ulmaceae were very infrequent. The majority of the *Juniperus* charcoal fragments represented twig or small branch-wood remains with some traumatic resin canals (resin canals are generally absent from *Juniperus* under normal growth conditions) and tension wood (see also Figures 5.1-5.3). The single fire feature sampled in this study (BIO, see also Table 5.2) yielded wood charcoal fragments comprising entirely of *Juniperus*.

The anthracological assemblage from the 9th millennium aceramic Neolithic occupations at Site A and Site D was much less diverse. Twenty-two dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999)including external fill/debris, structural debris, floor and midden deposits were analysed yielding 306 fragments identified to genus level and 172 indeterminate fragments (Table 5.4). Average density at 0.00268 g/l was slightly higher than that of the Epipalaeolithic anthracological assemblage. An overwhelming majority of the remains (98%) belonged to *Amygdalus* (see Table 5.5) several of which contained mineral deposits and appeared partially vitrified. Three fragments of deciduous *Quercus*, 2 fragments of *Pistacia* and 1 fragment of *Juniperus* were also identified in the Pınarbaşı Sites A/D 9th millennium assemblage.

5.2.2 Can Hasan III

A large portion of the Can Hasan III archaeobotanical assemblage retrieved by Gordon Hillman in the 1960s is stored at the British Institute in Ankara archaeobotany laboratory. Previous analyses by Willcox (1977, 1978, 1979, see also Willcox 1991, 1992) concentrated on charcoal fragments collected from dry sieving. Systematic quantification by ubiquity and fragment counts was not applied; taxon ubiquity has been only partially reported for the aceramic Neolithic anthracological assemblage. In the present study >2mm wood charcoal remains were sorted from the flotation samples stored in Ankara, in order to produce a dataset sufficiently large to enable its diachronic comparison with the anthracological assemblages derived from Pınarbaşı, Boncuklu and Çatalhöyük. Twenty-four samples from the aceramic Neolithic levels (trench 49L) excavated at Can Hasan III were studied, producing 675 fragments identified to genus or family level and 126 indeterminate fragments. A majority of the identified fragments, 662, derived from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) (22 samples) and 13 from primary fire features (Table 5.6). Density calculations were not carried out due to the unavailability of accurate sediment volume records. However, on qualitative grounds, charcoal preservation at Can Hasan III appears to be overall better by comparison to the Pınarbaşı assemblage; charcoal fragments were larger (commonly between 2-4mm in size). In dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), Ulmaceae were ubiquitous (being present in 87% of the samples) and also registered high abundance values (35%) (Table 5.7). *Ulmus* and *Celtis,* both of which belong to the Ulmaceae family, were much less frequent; genus-level identifications of Ulmaceae were generally hampered by the small size of the charcoal fragments. In addition, distinguishing between *Celtis* and *Ulmus* in small calibre wood specimens is often more difficult: the wood anatomical features of the two taxa tend to be more alike in under-developed (immature wood) specimens. Bearing in mind that a much lower number of *Ulmus* and *Celtis* fragments were identified (12 and 2 fragments respectively), *Ulmus* appears to be more abundant and ubiquitous compared to *Celtis* (Table 5.7).

Amygdalus charcoals were also ubiquitous (present in 78% of the samples) with 187 identified fragments (amounting to 28% of the total number of identified specimens). *Pistacia* was the third most abundant taxon (16% of the identified charcoal sum) being slightly more ubiquitous than *Amygdalus* (present in 82% of the analysed samples). Salicaceae, *Juniperus* and deciduous *Quercus* were also identified in lower quantities (33, 21 and 17 fragments respectively). *Pinus* cf. *nigra*, Maloideae, Chenopodiaceae, Leguminosae and *Capparis* fragments were rare; they were all present in less than 5 samples (Table 5.7). In addition, a number of fragments were classified as Ulmaceae/Anacardiaceae due to poor preservation and the absence of sufficient anatomical features in the specimens to permit more positive botanical identification. Furthermore, a small number of charcoal particles were identified as indeterminate twig, bark and conifer (gymnosperm) fragments. A single fragment was tentatively identified as a poorly developed dicotyledonous stem; it contained vascular bundles arranged in a circular ring around the pit. However, secondary thickening was not observed in the specimen. Therefore, it has been classified as a potential fragment of herbaceous or under-developed dicot stem (cf. dicot stem).

The two analysed fire features contained a very low number of identifiable specimens comprising 9 Ulmaceae and 3 *Amygdalus* fragments, and 1 *Pistacia* fragment (see Table 5.6). These finds in the primary fire features conform to the general abundance patterns observed in the wood charcoal remains retrieved from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999).

5.2.3 Boncuklu

Flotation samples from 4 excavated areas (trenches K, H, N and M) were scanned in order to assess wood charcoal density and guide sample selection. Wood charcoal densities of samples from 80 midden contexts, 57 building infill/structural debris contexts, 52 fire features and 69 floor contexts were calculated. Charcoal densities across the different contexts are generally low: midden average density is 0.00470 g/l, building infill/structural debris 0.00492 g/l, fire features 0.00599 g/l and floor deposits 0.0011 g/l (see also Table 5.8). Since a sufficiently high number of contexts were available, the distribution of wood charcoal densities across contexts was evaluated in greater detail (see Fig. 5.35). The frequencies of charcoal density values in different context types demonstrate that the majority of sampled contexts have lower than average density, while fewer samples have higher than average densities. Therefore, all context types conform to a skewed (log-normal) distribution. This suggests that depositional and post-depositional processes exert a significant impact in wood charcoal preservation in archaeological sediments. While density figures in dispersed contexts (i.e., middens and building infills, '*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) occupy a narrower range (0-0.02 g/l in middens, and 0-0.04 g/l in building infills) a wider range is observed in fire features (0-0.06 g/l) while the higher end of the primary fuel waste contexts contain higher charcoal density compared to dispersed contexts. This increasing variability in the density of charcoal remains retrieved from fire features may reflect the range of variation observed in the differential impacts of mass loss on wood fuel during combustion.

Shifts in the distribution of charcoal density ranges could also be considered as evidence for the frequency and intensity of wood fuel use during the timespan represented by each occupation phase. More frequent fuel waste disposal would lead to faster accumulation of charred remains and thus higher charcoal densities. A comparison of the range of wood charcoal densities between the Boncuklu and Pınarbaşı anthracological assemblages (Fig. 5.36) supports the view that fuel use at Boncuklu was potentially more frequent and intensive.

In the Boncuklu wood charcoal assemblage 1328 fragments from 75 contexts were examined, comprising 1020 fragments identified to genus or family level and 308 indeterminate fragments. Of the analysed samples 66 came from a range of dispersed contexts (midden, building infill and floor and occupation deposits, '*charbon de bois* *dispersés'* cf. Chabal 1992, Chabal et al. 1999) yielding 944 identified fragments; a further 9 samples derived from fire features, yielding 76 identified fragments (see Table 5.8). Due to the fact that site phasing has not been established for all excavated contexts, the results are presented by trench: K and H represent the earliest excavated occupation of the site while N and M are later. Due to the absence of external midden contexts from trench K, this trench is characterised by lower charcoal densities and, correspondingly, lower number of identified fragments (see also Table 5.9). It is also likely that charcoal taxa abundances in samples from this trench are not completely representative as the representation of dispersed deposits are limited. Salicaceae were the most abundant (41%) and ubiquitous (present in 82% of the samples) taxon in Trench K. *Pistacia* charcoal was also abundant (30% of the total number of identified fragments), but occurred in fewer samples (18% ubiquity), while *Amygdalus* was more common (36% ubiquity) but less abundant, accounting for 16% of the identified charcoal fragments from trench K. Low abundance and ubiquity values were observed for charcoals of *Artemisia*, Chenopodiaceae, *Juniperus* and deciduous *Quercus*. One internal fire feature from this trench contained a single fragment of *Amygdalus* (Table 5.8).

Twenty-three dispersed contexts (‘*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) were analysed from trench H, yielding 315 identified fragments (see Table 5.9). Of these an overwhelming majority belonged to Salicaceae (73%) which were present in 91% of the examined contexts. *Amygdalus* with 12% abundance was present in 50% of the analysed contexts. *Quercus*, *Pistacia*, Ulmaceae, *Fraxinus*, *Artemisia*, Chenopodiaceae, Leguminosae, *Capparis*, *Ephedra*, cf. *Arbutus*, cf. *Paliurus*/*Ziziphus*, cf. Euphorbiaceae and cf. Maloideae were also present in trench H in much lower quantities and more rarely. A number of these identifications are listed as cf. due to the small size and rarity of the specimens that did not preserve enough anatomical features. Trench H dispersed contexts (‘*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) also contained 1 fragment of indeterminate gymnosperm and 7 indeterminate twig fragments. 1 external and 3 internal fire features from trench H yielded 33 identified fragments (Table 5.8). The internal fire features were less diverse and contained numerous small fragments of Salicaceae, and 1 fragment of *Fraxinus*. The external fire feature comprised a similar proportion of Salicaceae alongside a few fragments of *Amygdalus* and *Pistacia*.

From the dispersed deposits in trench N (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), 10 contexts were studied yielding 281 identified and 98 indeterminate charcoal fragments (Table 5.9). Similar to the two previously discussed trenches, Salicaceae was the most ubiquitous and abundant taxon, being present in all sampled contexts and accounting for 53% of the identified fragments. *Amygdalus* was also ubiquitous (8/10 contexts) although with much lower abundance (9%). Leguminosae accounted for 11% of the identified fragments and were found in 4/10 contexts. *Tamarix* was recorded in 6 contexts, accounting for 9% of the identified fragments. The abundance of deciduous *Quercus* (21 fragments) accounting for 8% of the identified fragments and present in 4/10 contexts is highest in trench N compared to other trenches. Less frequent were *Juniperus*, *Pistacia*, *Prunus*, Ulmaceae, *Fraxinus*, *Artemisia*, cf. *Paliurus*/*Ziziphus*?, cf. Euphorbiaceae, cf. Anacardiaceae. In addition, 5 fragments of indeterminate twigs and 1 fragment of indeterminate root wood were also recorded. Two internal fire features analysed from trench N yielded 8 identified fragments (see Table 5.8). They were more diverse compared to fire features from trenches K and H. Charcoals of *Pistacia*, *Tamarix*, *Quercus*, Salicaceae and Ulmaceae were also recorded in these fire features.

Twenty-two dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) were studied from trench M yielding 257 identified fragments and 64 indeterminate fragments (see Table 5.9). Of these, the majority belonged to Salicaceae, occurring in all sampled contexts and accounting for 80% of the identified fragments from this trench. Deciduous *Quercus* and *Tamarix* were the next most abundant taxa, accounting for 5% and 4% of the identified fragments. The following taxa registered much lower abundance and ubiquity values: *Pinus* cf. *nigra*, *Juniperus*, *Amygdalus*, *Pistacia*, *Artemisia*, Chenopodiaceae, Leguminosae, *Capparis*, cf. *Paliurus*/*Ziziphus* and cf. Euphorbiaceae. In addition, 4 fragments of indeterminate twigs and 1 fragment of indeterminate root wood were recorded. Two external fire features were sampled from trench M yielding 34 fragments. These features were generally more diverse compared to those from previously trenches K, H and N (see Table 5.8) and comprised mostly Salicaceae charcoals alongside fragments of *Juniperus*, *Quercus*, *Amygdalus*, *Tamarix*, *Artemisia*, Chenopodiaceae and indeterminate twigs.

As outlined in section 5.1.1, dendroecological features of specimens from Boncuklu were not quantified due to the generally small sizes of specimens. However, the presence of fungal hyphae was commonly observed in the assemblage, occurring in some cases in severely degraded specimens with collapsed vessels and fibres.

5.2.4 Çatalhöyük

The evaluation of wood charcoal densities recorded across different contexts at Çatalhöyük (including anthracological assemblages from the Neolithic East and the Chalcolithic West mounds) revealed that density values (g/l) from dispersed contexts (e.g., middens, building infills, '*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) conform to the skewed (log-normal) distribution observed in the Boncuklu assemblage. However, at Çatalhöyük average density values (0.1259 g/l) and the range of observed values (up to 6.133 g/l) are much higher compared to Boncuklu (Fig. 5.37). This difference in density values may relate to two processes: the higher frequency and intensity of fuel wood use and the much faster rate of midden accumulation at Çatalhöyük. The lower density values observed in some phases (such as South I and South J) might reflect the lower number of excavated contexts from these levels. Charcoal densities began increasing during South H and continued increasing until the end of South P (see also Fig. 5.38). After this point, either midden accumulation became spatially more widespread, resulting in lower charcoal densities, or wood fuel use became less frequent. One possible interpretation of this pattern is that that the frequency of wood fuel use at Çatalhöyük increased through time. Furthermore, it is also possible that the later part of the sequence, which is also closer to the surface of the mound, could have undergone more severe post-depositional weathering and trampling, resulting in higher rates of charcoal fragmentation.

The distribution of wood charcoal density values from fire features at Çatalhöyük also reflects a skewed distribution, with a range of values similar to those obtained from dispersed contexts (see Fig. 5.37). It would thus appear that either dispersed contexts ('*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) often incorporate fast accumulated debris from short-lived fire features (resulting in a range of density values similar to that observed in fire features) or that comparable post-depositional taphonomic processes have impacted both types of deposits. The main differences observed between dispersed (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) and primary fuel waste contexts at Çatalhöyük are the degree of preservation (some primary fuel waste contexts contain better preserved specimens) and the diversity of taxa (dispersed contexts generally contain a broader range of taxa). In order to assess whether post-depositional conditions or rate of burial in dispersed contexts contribute to this overall distribution of density values, charcoal densities were evaluated against the taphonomic status of faunal remains derived from the same units. As part of routine recording practices the archaeozoological team at Çatalhöyük record the surface condition of faunal remains on an ordinal scale (good, moderate, high and variable), thus providing an independent measure of the rate of burial of faunal remains, and of the degree of weathering and trampling. Good and moderate surface conditions indicate relatively faster rate of burial: faunal remains would have been buried without a lengthy period of exposure on the surface. By contrast, high and variable weathering indicates prolonged trampling and surface exposure. As Figure 5.39 shows, a broad range of variability in density values is observed in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), including good, moderate and variable surface conditions. It should be noted that high surface weathering was only recorded in one context. In all cases, a higher number of contexts tend to have lower charcoal density while fewer contexts have above average charcoal density, as indicated by the lower placement of the average bar in the box plots. It follows from these observations that, regardless of surface conditions as deduced from bone taphonomy, pre-depositional (burning) and (post)depositional processes alike result in a skewed distribution of charcoal densities.

Interestingly, at both Boncuklu and Çatalhöyük, the combined spatial filter of depositional and post-depositional events appears to result in a low number of charcoal rich (denser) contexts and a high number of below-average density contexts, regardless of context type. Mass loss and fragmentation would thus appear to result in a skewed distribution reflecting the exponential cumulative effects of random events (trampling, weathering, etc.) and repeated activities (behavioural patterns relating to hearth structure and function, fuel waste disposal, etc.). Therefore, the law of fragmentation as proposed by Chabal (1992) who suggested that as a result of burning, burial and post-depositional disturbance wood charcoal remains will fragment in a manner that produces a high number of small-size fragments and a low number of large-size fragments is upheld.

Furthermore, this skewed distribution of charcoal densities appears to be largely independent of surface conditions and rate of deposition, as indicated by the evaluation of charcoal density values against bone taphonomy in dispersed contexts at Çatalhöyük (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999).

The Çatalhöyük East mound (Neolithic) anthracological assemblage analysed in the present study comprises charcoal samples from 39 midden contexts from all available excavated phases (South G-T and TP) yielding 2306 identified and 337 indeterminate fragments (Table 5.10). No verifiable dispersed contexts or midden samples were available from South N; therefore this phase is not represented in the following discussion. A further 39 primary fire features were also analysed from South P, South Q, South R and South S, which yielded 953 identified and 49 indeterminate fragments (Table 5.11). From the Çatalhöyük West mound (Chalcolithic) anthracological assemblage 11 dispersed contexts were analysed (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), including midden-like deposits, building infill and floor deposits. Due to the low resolution of the archaeological phasing and the low density of the charcoal materials this assemblage is presented as a single phase (Table 5.12). A further 4 primary fire features were analysed from the West mound resulting in 53 identified and 3 indeterminate fragments (also in Table 5.12).

The descriptive results of the anthracological analyses undertaken as part of the present study of taxon abundance at Çatalhöyük are presented below (sub-sections 5.2.4.1-5.2.4.13) starting from the earliest excavated phase (South G(early)) and ending with the latest period of occupation (West mound). Ubiquity (sample presence) values were calculated after integrating the results obtained from the present study with those published by Asouti (2005, 2013) in order to get a more representative picture of presence/absence of taxa through time. The ubiquity results are discussed in sub-section 5.2.4.14. The results of the present study were incorporated into the available anthracological dataset from the sites under study in order to evaluate long-term shifts in fuel use in the Konya plain (see Table 5.13a and Table 5.13b), utilizing published datasets from Asouti (2002, 2005 and 2013). A more comprehensive diachronic evaluation of anthracological finds from dispersed contexts (‘*charbon de bois dispersés*’ cf. Chabal 1992, Chabal et al. 1999) is presented in section 5.3.

As noted by Asouti (2002, 2005, 2013), the anthracological assemblage compositions reflects a stratigraphic separation between the earlier and later levels of South G (i.e., Mellaart levels pre-XII C-E (early) and pre-XII A-B (late) following the previous phasing of the site). The same shift in sample composition in midden samples from South G levels were also observed in the results of analyses of the present study. Therefore, in the sequence below and throughout the rest of the thesis, South G (early) refers to the earlier levels (i.e. pre-XII C-E) of this phase, and South G(late)–H refers to the later levels (i.e. pre-XII A-B) and South H.

5.2.4.1 South G (early)

Two midden samples were analysed from South G(early), yielding 85 identified fragments and 35 indeterminate fragments (see Table 5.14). Of these, Ulmaceae (including *Ulmus* and *Celtis*) were the most abundant (42%). *Celtis* was more abundant than *Ulmus* (25 and 9 fragments respectively). Salicaceae fragments accounted for 21% of the identified fragments while deciduous *Quercus* fragments formed only 11% of the charcoal fragment count from this phase. These observations on taxon abundance are in general agreement with previously analysed samples from this phase (Asouti 2002, 2005). *Juniperus*, *Amygdalus*, *Pistacia*, Maloideae, *Artemisia* and Leguminosae were also recorded in samples from this phase (see also Table 5.10).

5.2.4.2 South G(late)–H

Two midden samples were analysed from this phase producing 200 identified and 28 indeterminate fragments (Table 5.14). Previous publications of the earlier phases of the Çatalhöyük wood charcoal assemblage (Asouti 2002, 2005) reported a shift in taxon abundance values of *Quercus* within the South G sequence, whereby the later part of this phase reflected a taxon distribution more similar to that observed in South H (see Table 5.10 for per-sample charcoal counts). This observation was replicated in the present study with one of the South G midden samples (unit 4866) reflecting much higher counts of *Quercus*; it was thus grouped with the South H midden sample in the diachronic evaluation of site-wide patterns in charcoal representation. In South G(late)–H, Ulmaceae (including *Ulmus* and *Celtis*) remain important components of the assemblage with 39% abundance (Ulmaceae 16%, *Ulmus* 13%, *Celtis* 10%). However, unlike South G(early), *Ulmus* is more abundant compared to *Celtis*. Salicaceae frequencies (20%) are also comparable to those recorded in the previous phase, while *Quercus* charcoals account for 26% of the total number of identified fragments. The following taxa also registered much lower abundance values: *Juniperus*, *Amygdalus*, *Prunus*, Maloideae, Anacardiaceae, *Rhamnus*, Chenopodiaceae, *Artemisia* and Leguminosae. In addition 5 fragments of indeterminate twigs and 3 fragments of indeterminate bark were also recorded (see Tables 5.14 and 5.10).

5.2.4.3 South K

Three midden contexts from this phase were analysed in the present study, yielding 250 identified, and 53 indeterminate fragments (Table 5.14). Ulmaceae with an abundance of 35% (including *Ulmus* (8%) and *Celtis* (14%)) remained the most abundant taxon in this phase, although at a slightly lower percentage frequency compared to the previous two phases. Values for Salicaceae were also slightly lower at 17%, while *Quercus* accounted for 24% of charcoal sample composition. Less frequent were *Juniperus*, *Pistacia*, Maloideae, Anacardiaceae, *Fraxinus*, *Acer*, Chenopodiaceae, *Artemisia*, Leguminosae, *Capparis*, *Tamarix*, Labiatae, and Rosaceae (comprising *Amygdalus* and/or *Prunus*). With 18 different taxa, South K held the most diverse charcoal assemblage amongst the Çatalhöyük sampled phases. Three fragments of indeterminate twigs were also recorded in the samples analysed from this phase (see Table 5.10).

5.2.4.4 South L

Three midden contexts from this phase yielded 200 identified specimens and 36 indeterminate fragments (Table 5.14). In this level *Quercus* (42%) was the most abundant taxon, followed by *Ulmus* (17%) and *Celtis* (13%). Salicaceae at 11% were less abundant compared to earlier phases. *Fraxinus* (10%) was also an important component of the assemblage. The following taxa were recorded in much lower abundances: *Juniperus*, *Prunus*, Maloideae, Anacardiaceae, Chenopodiaceae, *Artemisia*, Leguminosae and *Capparis*. Three fragments of indeterminate twigs were also recorded (see also Table 5.10).

5.2.4.5 South M

One midden context from South M was examined yielding 50 identified and 8 indeterminate fragments (see also Tables 5.14 and 5.10). Despite the small size of the assemblage available from this phase, the anthracological results are in general agreement with previous analyses of midden contexts from South M (Asouti 2005, 2013). *Quercus* and Ulmaceae (both with 23 fragments) were the most abundant taxa. *Juniperus*, Salicaceae and *Capparis* registered much lower abundance values.

5.2.4.6 South O

Two midden contexts from South O were examined yielding 175 identified fragments and 10 indeterminate fragments (see Tables 5.14 and 5.10). *Quercus* was the most abundant taxon (45%), followed by *Juniperus* (21%). *Ulmus* and Salicaceae (both at 9%) were also important elements of the assemblage, while values for *Celtis* were very low (<1%). The following taxa registered lower abundance values: *Amygdalus*, *Pistacia*, Maloideae, Anacardiaceae, Ulmaceae, Leguminosae and *Tamarix*. In addition, 2 fragments of indeterminate twig were recorded.

5.2.4.7 South P

Four midden contexts from South P were analysed yielding 350 identified fragments and 56 indeterminate fragments (Table 5.14). *Quercus* (42%) was the most abundant taxon, followed by Ulmaceae (25% - including *Ulmus* (6%) and *Celtis* (4%)). Salicaceae fragments accounted for 23% of the total number of identified fragments. The following taxa also registered much lower abundance values: *Juniperus*, *Amygdalus*, *Pistacia*, *Prunus*, Maloideae, *Artemisia*, Leguminosae, *Capparis* and *Tamarix*. In addition, 8 fragments of indeterminate twigs, 1 fragment of indeterminate bark and 1 fragment of dicot stem (cf.) were recorded (Table 5.10).

Twenty-four contexts representing primary fuel waste debris, including hearth fill, oven fill, fire spot and ashy rake-out, were also examined from South P, yielding 693 identified fragments and 37 indeterminate fragments (Table 5.11). These contexts were dominated by *Quercus*, which amounted to 53% of the total number of identified fragments from South P primary fire features. Ulmaceae (19%, including *Ulmus* (3%)

and *Celtis* (2%)) and *Juniperus* (13%) were also important elements of charcoal sample composition. The following taxa were identified in lower frequencies: *Amygdalus*, *Pistacia*, *Prunus*, Salicaceae, *Fraxinus, Tamarix, Artemisia*, Chenopodiaceae, Leguminosae and *Capparis*. In addition, 4 fragments of indeterminate twigs, 3 fragments of indeterminate bark and 1 fragment of root wood were recorded in primary fuel waste deposits from this phase.

5.2.4.8 South Q

Four midden contexts were analysed from this phase yielding 225 identified fragments and 19 indeterminate fragments (Tables 5.10 and 5.14). The most abundant taxa were *Quercus* (28%) and *Juniperus* (27%) followed by Ulmaceae at 18% (including *Ulmus* (5%) and *Celtis* (2%)). Salicaceae and *Fraxinus* (both at 9%) were also important elements of the assemblage. The following taxa were identified at much lower abundance values: *Amygdalus*, *Pistacia*, *Artemisia* and *Tamarix*. Two fragments of indeterminate bark were recorded in samples from this phase. In addition, 8 primary fuel waste contexts, including oven fill, hearth fill and fire spot deposits, from this phase were examined yielding 164 identified fragments and 3 indeterminate fragments (Table 5.11). The majority of these fragments consisted of *Quercus* (34%) and *Juniperus* (30%). The remainder of the identified fragments from primary fuel waste contexts belonged to *Fraxinus*.

5.2.4.9 South R

Six midden contexts were examined from this phase yielding 280 identified fragments and 31 indeterminate fragments (Tables 5.10 and 5.14). The most abundant taxon was *Juniperus* (41%) followed by *Quercus* (19%) and *Fraxinus* (15%). Ulmaceae at 14% (including *Ulmus* (1%) and *Celtis* (2.5%)) were also important elements of the assemblage. *Amygdalus* (8%) reached its highest frequency in this phase across the Çatalhöyük anthracological assemblage. The following taxa were also recorded with fewer fragments: *Pistacia*, Salicaceae and *Acer*. Six contexts from fire spots were also examined from South R yielding 63 identified fragments and 9 indeterminate fragments (Table 5.11). A great majority of these fragments consisted of *Juniperus* (57%) and *Fraxinus* (16%). Ulmaceae (16% - including *Ulmus* (5%) and *Celtis* (3%)) were also an important element of charcoal sample composition. Fewer fragments of *Amygdalus* and *Artemisia* were recorded in these fire spots samples.

5.2.4.10 South S

Three midden contexts belonging to South S were analysed yielding 106 identified fragments and 8 indeterminate fragments (Tables 5.10 and 5.14). The majority of the samples consisted of *Juniperus* (37%) followed by *Fraxinus* (20%) and *Quercus* (19%). *Pistacia* (11%) and *Amygdalus* (8%) were also important elements of the South S anthracological assemblage. The following taxa recorded much lower abundance values: Ulmaceae, *Celtis* and *Artemisia*. One fire spot context from this phase was also examined yielding 25 identified fragments of *Quercus* (Table 5.11).

5.2.4.11 South T

Five midden contexts were examined from South T, yielding 172 identified fragments and 10 indeterminate fragments (Tables 5.10 and 5.14). *Juniperus* (53%) was the most abundant taxon, followed by *Quercus* (16%), *Pistacia* and Ulmaceae (8%) and *Amygdalus* (7%). *Fraxinus* and Salicaceae were also recorded with fewer fragments.

5.2.4.12 TP Area

Four midden contexts from the TP phases were examined, yielding 210 identified fragments and 24 indeterminate fragments (Tables 5.10 and 5.14). Ulmaceae (44% - including *Ulmus* (15%) and *Celtis* (14%) were the most abundant taxon, followed by *Juniperus* (18%) and *Quercus* (15%). Salicaceae (8%), *Amygdalus* (6%) and *Fraxinus* (3%) were also important elements of the assemblage. The following taxa were also recorded with fewer fragments: *Pistacia*, Maloideae, *Artemisia* and Leguminosae. In addition, 3 fragments of indeterminate twigs were recorded.

5.2.4.13 West Mound

Eleven dispersed contexts, including middens, building infills and floor deposits (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), were analysed from the West mound, yielding 468 identified fragments and 46 indeterminate fragments

(Tables 5.12 and 5.15). *Juniperus* was the most abundant taxon (42%) followed by Ulmaceae (33% - including *Ulmus* (3%) and *Celtis* (3%)). *Quercus* (10%) was also an important element of the assemblage. The following taxa were recorded in lower frequencies: *Amygdalus, Pistacia,* Maloideae, *Prunus,* Salicaceae, *Fraxinus, Acer, Tamarix, Artemisia,* Chenopodiaceae and Leguminosae. In addition, 1 indeterminate twig fragment and 1 bark fragment were recorded. Four primary fire deposits including hearth fill, oven fill and ashy rake-out contexts were also examined, yielding 53 identified fragments and 3 indeterminate fragments (see Table 5.12). Hearth and oven fill deposits were generally diverse, including taxa such as *Juniperus*, *Quercus*, *Amygdalus*, *Prunus*, *Pistacia*, Ulmaceae, *Fraxinus*, *Tamarix* and Leguminosae.

5.2.4.14 Taxon ubiquity in the Çatalhöyük anthracological assemblage

Ubiquity scores for the Çatalhöyük anthracological assemblage were calculated solely for dispersed contexts (*'charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) (i.e., excluding fire features), as these context types are more likely to provide a representative picture of the diversity of fuel wood use through time. It should be noted that results from some phases might be biased (e.g., South J, South O) due to the small number of the analysed contexts. The main temporal trends observed in taxon ubiquity are described below (full results are included in Table 5.16 for the East mound samples and Table 5.15 for the West mound samples).

Deciduous *Quercus* is the most ubiquitous taxon in all phases post-dating South G through to South S, which is in accordance with the pattern observed in abundance (percentage fragment counts) for this taxon through the greater part of the sampled sequence (see Table 5.16). The lower abundance values of *Quercus* in the TP and West mound samples are also closely linked to their correspondingly low ubiquity scores. On the other hand, while *Juniperus* remains are less abundant in the earlier phases (South G-Q), the ubiquity of this taxon increases rapidly, especially in South K and later phases In South K, while *Juniperus* is present in 67% of the samples (6 out of 9), the abundance of this taxon is still fairly low. After South K the ubiquity and abundance of *Juniperus* increase, and remain high through to the end of the sampled East mound South Area sequence, as well as in the TP and the West mound charcoal assemblages.

Salicaceae, Ulmaceae, *Ulmus* and *Celtis* follow similar trajectories in terms of their ubiquity scores through time. Both Ulmaceae (including *Ulmus* and *Celtis*) and Salicaceae are present in at least 90% of the samples in the early-middle phases of the East mound sequence (from South G(early) through to South P). After South P, Salicaceae are less ubiquitous and less abundant, while Ulmaceae remain an important element of the assemblage through the middle-late part of the South Area sequence (South P-R). Both Ulmaceae and Salicaceae are present in fewer samples in South S-T. Ulmaceae, represented more commonly by *Ulmus*, are more ubiquitous and more abundant in the TP and West mound samples compared to the earlier phases. Salicaceae are also more ubiquitous in the TP samples, but are less commonly found in the West mound samples.

While the more common riparian taxa (Ulmaceae and Salicaceae) are present in all phases, *Fraxinus* does not register any significant proportions until the later phases of the East mound sequence. In South Q *Fraxinus* occurs in the majority of the charcoal samples (5/6). *Fraxinus* remains ubiquitous through to the end of the East mound sequence (South Q-T and TP) and becomes less common among the West mound charcoal samples.

Wood charcoals from taxa such as *Pistacia*, *Amygdalus* and Maloideae, all of which formed important sources of wild fruits and nuts, appear mostly as small round wood (see below sections 5.4-5.5), and generally register low abundance values and ubiquity scores. *Pistacia* and *Amygdalus*, while present in all phases of the sampled sequence, are generally rare. During the earliest excavated phase of Neolithic occupation (South G(early)) *Pistacia* and *Amygdalus* are present in more than 50% of the sampled contexts. Both taxa become less ubiquitous through phases South I-M. After South M, they become more abundant and more ubiquitous, a pattern that continues to the end of the South Area phases, and through the TP and West mound phases.

Artemisia is more common in some earlier phases (South G(late)–H, K, L and M) while it appears sporadically in other phases. Chenopodiaceae and Leguminosae are also more common in phases South K, L and M. It is noteworthy that these three phases contain the most diverse samples across the Çatalhöyük East and West mounds sampled stratigraphy; it is possible that the more regular occurrence of shrubby taxa in these samples is related to their overall better preservation.

When abundance values and ubiquity scores are considered together it becomes apparent that throughout the sampled sequence at Çatalhöyük wood fuel use comprised a broad range of taxa covering a number of distinct ecological zones, with a strong chronological element. In the next section the main temporal trends observed in the quantified anthracological results obtained from all sampled sites in the Konya plain sites are described.

5.3 Diachronic evaluation of the Konya plain anthracological assemblage

In order to evaluate major shifts in fuel wood selection and use in the Konya plain encompassing the entire anthracological sequence beginning with the Epipalaeolithic habitation at Pınarbaşı and ending with the Chalcolithic settlement at Çatalhöyük West (~16-7.5 ka cal. BP) percentage fragment counts (calculated on the basis of identified charcoal sums) from all anthracological assemblages described in section 5.2 were combined, also incorporating previously published datasets from the Konya plain (Asouti 2003a, 2005, 2013). The resulting dataset is presented in the form of two anthracological diagrams (see Figures 5.40, 5.41; also Tables 5.13a and 5.17) arranged in chronological order. Figure 5.40 presents the results from all sampled Pınarbaşı sites (including Epipalaeolithic, Early (aceramic) Neolithic, Late Neolithic and Chalcolithic habitations). The anthracological diagram reveals that *Amygdalus* wood formed an important fuel source throughout the sampled sequence at Pınarbaşı. Interestingly, in the earliest known phase of occupation corresponding to the Epipaleolithic period there is also some use of *Juniperus*, mostly in the form of small branches and twigs. After this phase, *Juniperus* wood either became very rare in the vicinity of the site, or it was not selected as fuel. Throughout the sampled sequence there is some indication that a diverse Rosaceae-dominated woodland ecology (including *Amygdalus*, *Prunus* and Maloideae) prevailed in the Karadağ foothill zone. Some riparian woodland taxa are also present in very small quantities, in addition to herbs and shrubs characteristic of drier habitats (e.g., *Artemisia*, Chenopodiaceae, and Leguminosae). Remarkably, the two most prominent taxa of the sampled sequence at Pınarbaşı (*Amygdalus* and

Pistacia) are present in all anthracological assemblages examined from the Konya plain, irrespective of time period, though never as abundant and ubiquitous as in Pınarbaşı.

As Figure 5.41 demonstrates, during the earliest sampled phases at Boncuklu (K, H, N) and at Can Hasan III, *Amygdalus* and *Pistacia* supplement fuel wood use, although at much lower proportions. Instead, the focus seems to be on wetland and riparian taxa. The use of riparian taxa as fuel is prominent in most phases of the Konya plain sites. In the earlier phases (i.e., at Boncuklu, Can Hasan III and Çatalhöyük South G(early)) the majority of fuel wood came from a diverse range of wet woodlands, in some cases dominated by Salicaceae (e.g., at Boncuklu) and in others by Ulmaceae (e.g., at Can Hasan III and parts of the Çatalhöyük sequence). Overall, the use of riparian taxa decreased in the transition from South G to G–H, yet their relative abundance and ubiquity remained fairly stable throughout the later part of the sequence. Towards the end of the Çatalhöyük East mound South Area sequence (i.e., in South Q, R, S, T) Ulmaceae and Salicaceae become less frequent; in these phases the focus seems to have shifted to another riparian taxon, *Fraxinus*. In the TP area and the West mound occupation Ulmaceae and Salicaceae increase in abundance once more while *Fraxinus* proportions decrease.

Deciduous *Quercus* is present in all phases examined from the Konya plain sites dating to the early-mid Holocene (Figures 5.40, 5.41). The earliest phases of the Çatalhöyük sequence (South G(early)) and the end of the Boncuklu sequence (M) mirror the beginning of a gradual increase in the use of *Quercus* fuel wood in the Konya plain (Fig. 5.41). While *Quercus* values represent 3% of the total number of identified fragments in South G(early), a rapid increase is observed during the final phase of South G(late) and in South H up to a maximum of 53%. This increase is also matched by a concurrent increase in *Quercus* ubiquity scores (see above, section 5.4.2.14). From South G(late)–H, *Quercus* becomes a frequent and dominant element of the Çatalhöyük fuel economy until the end of South P, accounting for ~50% of charcoal sample composition. In the transition between South P-Q, *Quercus* values drop from 43% to 27% and continue to decrease gradually in South R, S, T and in the TP and West mound assemblages. In these final phases of the Çatalhöyük sequence *Juniperus* becomes more abundant and ubiquitous (see Fig. 5.41, Table 5.17).

As mentioned already, *Juniperus* is found in noteworthy proportions in the Pınarbaşı B Epipalaeolithic assemblage. However, it does not become a prominent component of the regional fuel economies until much later, well after the mid-Çatalhöyük sequence. Despite this low-level use, *Juniperus* was retrieved from all sampled sites and is present in almost all phases of occupation (with the exception of Boncuklu trench H and the Pınarbaşı Chalcolithic phases previously reported by Asouti 2003a). In fact, until Çatalhöyük South K, *Juniperus* accounts for <5% of charcoal sample composition. Its apparent increase in South O to 20% may represent, at least in part, an artefact of the low number of samples analysed from this phase, in light also of the fact that juniper quantities drop again in South P. From South P-Q, *Juniperus* abundance values increase to 34% and reach their peak in South S (67%). In South T, juniper's abundance values and ubiquity scores drop and remain fairly low during the TP occupation. *Juniperus* becomes once more common in the West mound charcoal samples; it accounts for 42% of all identified fragments and is present in all the samples dating from this period.

5.4 Results of qualitative dendroecological analyses

As outlined earlier in this chapter (section 5.1.1), a number of dendroecological characteristics and qualitative aspects of growth ring anatomy were recorded for every specimen identified in the Çatalhöyük anthracological assemblage (East and West mound). The results of these analyses are investigated further in the following sections using multivariate techniques. This section provides a concise account of their main findings.

Concerning specimens recorded from dispersed contexts (i.e., middens, building infills and floor deposits, '*charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) from the Çatalhöyük East and West mound assemblages (see also Tables 5.18 and 5.19), a great proportion of the identified fragments could not be assigned with a curvature degree value (1, 2, or 3) due to the small size of the specimen and/or the difficulty in observing multiple growth rings clearly under the microscope. The same holds true for specimens observed from primary fuel waste deposits (see Tables 5.18 and 5.20).

Overall, in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), the highest number of curvature degree observations belonged to class 2 (moderately curved rings) with 850 observations, followed by class 3 (strongly curved rings) with 733 observations. Interestingly, class 1 (weakly curved rings), which is proposed to reflect the larger diameter classes, was recorded only for 137 specimens. Similar proportions for all classes were observed for specimens derived from primary fuel waste deposits, with class 2 most frequently observed (319 occurrences), followed by class 3 (225 occurrences) and class 1 (13 occurrences) (see also Table 5.20).

The most frequently observed qualitative feature was the presence of tyloses in both dispersed and primary fuel waste deposits (1802 and 620 observations respectively) (see Tables 5.18-5.20). This was followed by fungal hyphae with 1335 observations in specimens from dispersed contexts and 610 observations in specimens from primary fuel waste deposits. Proportionally, fire features contained more specimens with fungal hyphae (610 out of 994) compared to dispersed contexts (1335 out of 2768). The presence of resin canals/gum ducts in fragments from dispersed contexts (599 observations) was more common compared to the presence of narrow growth rings (424 observations). On the other hand, narrow growth rings (177 observations) were more frequent in primary fuel waste deposits than resin canals/gum ducts (144 observations). Knot wood, collapsed vessels/tracheids, radial cracks, mineral deposits, reaction wood, bore holes and scar/callus tissue were also recorded at much lower frequencies in both context types.

When curvature degree classes for dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) are tabulated per phase (Table 5.19) the following phases contain a higher number of class 3 (strongly curved) observations than class 2 (moderately curved): South G(late)–H, South K, South P and South S. Furthermore, South L contains the highest proportion of class 1 (weakly curved) specimens (56 out of 199 observations) (Table 5.19). Curvature degree classes also display different distributions amongst different taxa for both dispersed (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) and fire feature contexts (Figures 5.42-5.43). The highest frequencies of curvature degree 1 (weakly curved) fragments amongst all taxa are observed for *Quercus*. Furthermore, a majority of the fragments from *Quercus*, along with *Juniperus* and *Ulmus*, belong to curvature degree class 2 (moderately curved). This distribution of curvature degree classes suggests the presence of larger calibre wood from these taxa; this point is further explored in section 5.5 alongside the results of the diameter estimation measurements.

Fruit/nut bearing taxa such as *Amygdalus*, *Pistacia*, Maloideae and *Celtis* consist mostly of curvature degree class 3 specimens, suggesting their use mostly in the form of smaller sized branches and twigs (Figures 5.42-5.43). These observations on *Amygdalus, Pistacia*, Maloideae and *Celtis* are in agreement with previous qualitative observations on these taxa from Çatalhöyük (see Asouti 2005, 2013). In addition *Juniperus*, Ulmaceae, Salicaceae and *Fraxinus* include numerous fragments that were not assigned a curvature degree class due to their small size and/or poor preservation or the specific qualities of their wood anatomy. The latter is particularly the case with *Juniperus* that does not have clearly visible rays in the transverse section and contains mostly narrow growth rings, sometimes including false rings, or naturally wavy ring boundaries. Salicaceae growth ring boundaries are often indistinct, particularly in dead/decayed wood; thus estimating the curvature degree of Salicaceae fragments (even of large sized ones) is often not feasible.

Some primary fuel waste debris contexts (fire spots) from South P contained proportionally higher numbers of twigs preserving pith or bark, which suggests that the preservation conditions in some of these contexts were particularly favourable. One such context is unit (17082) that contained a large number of Ulmaceae and Salicaceae twigs, and Leguminosae and *Artemisia* fragments with pith and bark partially preserved. Taxa such as *Ulmus*, *Celtis*, *Quercus* and *Fraxinus* display some differences in the distribution of curvature degree classes when midden and fire feature contexts are compared (Figures 5.42-5.43). The plots show that primary fuel waste contexts contain a higher proportion of *Ulmus*, *Celtis* and *Quercus* charcoal fragments belonging to curvature degree 2 and a lower proportion to curvature degree 3, when compared to their distribution in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999). Thus primary fuel waste deposits represent some larger diameter specimens in relatively higher numbers. Conversely, *Fraxinus* charcoals from fire features display a higher incidence of curvature degree 3 observations.

5.5 Results of quantitative dendroecological analyses

Quantitative methods of dendroecological analysis (minimum diameter and growth ring width estimations) were applied to a sub-sample of the specimens that were recorded through qualitative dendrological analyses (curvature degree classes). These included 150 specimens belonging to *Quercus*, *Fraxinus*, *Ulmus* and *Celtis* from midden contexts covering all phases of the Çatalhöyük East mound sequence and the West mound assemblage, plus 32 specimens of the same taxa from primary fuel waste contexts in South P, Q and R. As described in section 5.1.1, diameter estimations were calculated using the trigonometric tool developed by Paradis et al. (2013) (Fig. 5.30). Measurements of distance between rays, angle between rays and growth ring width (radially from the beginning of the early wood portion of each ring to the end of the latewood portion) were recorded in millimetres. The distribution of the results of diameter measurements by taxon is presented in Figure 5.44. These results indicate that *Quercus* and *Fraxinus* fragments were derived from larger diameter logs compared to *Ulmus* and *Celtis*. Interestingly, in midden contexts *Fraxinus*, *Ulmus* and *Celtis* are represented with a wider range of diameter sizes compared to their representation among primary fire features (Fig. 5.44). While *Quercus* fragments are also represented with a wide diameter range in midden contexts, some fire features provided very large diameter size estimations for this taxon (>400mm). However, generally, for all taxa to which quantitative dendroecological analyses were applied, large diameter sizes (>200mm) are very rare, although they occur in almost all phases (Fig. 5.45; see also Figures 5.46, 5.47). As Figure 5.45 shows, the distribution of diameter measurements is comparable in secondary (midden) and primary (fire feature) contexts, reflecting a similar tendency for the preservation of smaller diameter specimens most likely coming from heartwood, thus suggesting that the skewed distribution of diameter size (left-skewed) cannot be accounted by the effects of post-depositional processes alone. This situation might arise from the combined effects of the consumption of larger diameter portions of wood during burning and subsequent fragmentation prior to deposition.

When per-phase diameter measurements from all four taxa are evaluated together (Fig. 5.46) it becomes evident that the number of per-phase measurements has a significant effect in the representativeness of the ranges of diameter estimations. A minimum sample size of at least 15 measurements per phase would have provided an ideal population. Due to preservation issues and limitations resulting from wood anatomy and the limited availability of suitable samples more measurements were not feasible for certain phases. Phases which contain a larger number of observations (e.g., South K, L, P, Q, and the TP assemblage) strongly suggest the presence of a skewed distribution of diameter sizes, with specimens of smaller minimum diameter represented in much higher proportions compared to larger diameter sizes.

This uneven pattern of the distribution of diameter sizes was investigated more closely in order to evaluate the coherence of the dataset with regard to the representativeness of the range (minimum and maximum) and median values of diameter sizes across the assemblage. A histogram of all diameter measurements from all phases was tested for goodness-of-fit using the three main skewed distributions (left): lognormal, gamma and Weibull. The resulting theoretical distributions were plotted against the actual dataset. As Figure 5.48a shows, the best fit for the dataset is the lognormal distribution. Table 5.21 shows the comparison of the goodness-of-fit statistics for the three distributions evaluated against the dataset, all of which suggest that the lognormal is the best fit for the dataset. Figure 5.48b shows the dataset fitted with a lognormal density line. The Q-Q, CDF and P-P plots compare the observed (empirical) and the theoretical (ideal) probabilities based on a lognormal distribution. As this evaluation demonstrates, diameter measurement data across the sampled phases at Çatalhöyük adhere to a lognormal distribution. The interpretative implication is that small-size diameter classes are predominant in the anthracological assemblage and that large-size classes are under-represented.

The theoretical utility of the lognormal distribution, similar to that of a normal (or Gaussian) distribution, lies in the modelling of the potential impacts of independent events (or variables, conditions, etc.) on a random sub-sample of a larger population. In effect, understanding the nature of such distributions allows for the evaluation of the represented minimum, maximum and typical individuals of a given dataset. In a lognormal distribution, a number of random variables are predicted to impact on a population in exponential ways, whereas in a normally distributed dataset, these impacts are said to be uniform and additive. Since diameter measurements across the analysed assemblage (comprising 182 charcoal fragments) reflect a lognormal distribution, it is likely that the random effects of mass-loss during burning, fuel waste disposal activities and mechanical post-depositional impacts have resulted in the under-representation of fragments of larger estimated diameter. This situation could result from the complete combustion of the outer rings (sapwood) of wood logs during burning. This phenomenon, in conjunction with the use of branch/round wood and twigs as fuel, could account for the over-representation of smaller diameter size classes. Therefore, the prevalence of smaller diameter fragments reflects not only the regular use of branch wood and twigs as fuel, but also the higher likelihood of the survival of heartwood (closer to the pith) in discarded hearth waste debris. The possibility that heartwood is preferentially preserved is further supported by the results of the qualitative dendroecological analyses discussed in the previous section, which indicate that the majority of the examined specimens displayed tyloses, an anatomical feature typically associated with heartwood.

A closer inspection of diameter estimation measurements for *Quercus* tabulated by phase of occupation (Fig. 5.47) reveals that the lowest maximum diameter calculations derive from South R, the TP Area, and the West mound. The widest range of *Quercus* diameter measurements derive from South P. Interestingly, despite the small sample size, larger diameter fragments (>200 mm) are also present in South G(late)–H, M, Q, and S. Thus, in phases when *Quercus* is the dominant fuel wood source, a minimum diameter of at least 200 mm is generally evidenced for this taxon (with the exception of South O). However, in some of the later phases when *Quercus* is less frequently used as fuel (e.g., South Q, South S), diameter sizes reflect the presence of similar ranges (at least 200mm). *Ulmus* fragments from most phases of occupation (South G(late)–H, K and L) are of a much smaller diameter range (i.e. <100 mm) (Fig. 5.49). The maximum diameter measurement for *Ulmus* comes from the TP midden contexts, which is also the phase with the highest abundance of *Ulmus* remains in the Çatalhöyük anthracological assemblage. Figure 5.50 indicates similar narrow ranges for *Celtis*. However, in South G(late)–H, R and in the West mound, calibre estimations >100 mm were found for this taxon. By contrast, *Fraxinus* fragments consistently display wider diameter ranges (see Fig. 5.51). South R, which is also contains the highest proportions for this taxon, contains specimens with a minimum estimated diameter of ~300mm.

In addition to estimated diameter calculations, all visible growth rings of all analysed specimens were measured and recorded (from the outermost to the innermost growth ring). In order to assess the existence of univariate or multivariate relationships between diameter size and growth ring width, a number of calculations were performed: average and median growth ring width were calculated for each taxon (by computing the average or the median value of all growth ring width measurements performed on each specimen). Maximum and minimum growth ring measurements for each taxon were also recorded, in addition to a measure of variability in growth ring size within the same specimen (i.e., delta=minimum growth ring width subtracted from maximum growth ring width). The scatter plots of diameter size and growth ring width measurements for each specimen are presented in Figures 5.52-5.57. They demonstrate that there is a great degree of variability in average, minimum, maximum and median growth ring width, which do not display a unilinear relationship to diameter sizes. This seems to hold true for all taxa included in the measurements. The lack of a unilinear relationship between ring width and diameter estimation suggests that variability in ring width measurements is not affected by the size/age of the logs from which wood charcoal specimens derived. Therefore, ring width size ranges and the variability in values for each taxon can be evaluated with regard to growth conditions regardless of diameter size ranges. The greatest range of variability is observed in the <100mm diameter sizes. A majority of the specimens exhibit average and median ring width <1mm, while a second group (comprising fewer individuals) contains median and average ring width of 1-2mm. Minimum ring width in several specimens is <1mm and maximum ring width <2mm. Interestingly, a majority of the specimens display delta ring width values of 0-1mm, and appear to be evenly distributed across diameter size classes. These findings suggest that growth ring width (thus, by implication, annual growth conditions and tree physiology) is largely unrelated to the size and calibre of each specimen. To explore further potential multivariate relationships in ring width and diameter, the same variables were evaluated with Principal Components Analysis (PCA). As the variable factor map shows (Fig. 5.58) the average, median, maximum and minimum ring width values follow a similar patterning in the dataset. All these variables have a very low degree of relationship (close to 0, as indicated by the nearly 90° angle of the plotted variables) while delta ring width values contribute very little to data patterning; they appear to be more or less closely related to maximum and average ring width. Diameter and angle between rays are negatively related to a high degree, as is expected from wood anatomical properties: as diameter increases the angle between two rays becomes narrower.

Per-phase ring width measurements for each taxon were also evaluated, in order to detect the modality of growth ring width and whether any changes in it through time could be attributed to temporal changes in taxon representation. As discussed already in Chapter 4, the impacts of management strategies on growth ring morphology and anatomy often impact ring width, regardless of stem diameter size (twig, branch, trunk wood). Strong selective pressures resulting from management strategies (e.g., pruning, lopping, pollarding) are expected to result in series of evenly distributed narrow rings (corresponding to cutting/defoliation and regrowth periods) interspersed by groups of wider rings (corresponding to periods of normal growth) signifying cycles of improved conditions and/or more rigorous growth in response to management practices (e.g., coppicing cycles and rotation).

Figures 5.59 and 5.60 show the distribution of *Ulmus* and *Celtis* ring width, which (beginning with South K) displays a limited number of years of growth release (i.e. an abrupt increase in ring width). In *Celtis* the wide range of ring width distribution (0.5-2.5 mm) is detected from the earliest phases, suggesting that some form of selective pressure was impacting differential growth of some individuals. Interestingly, when a clearer separation in wider ring width is observed (indicating growth release years) (in South K, L and P) minimum ring width is narrower while the wider ranges are clustered between 1-1.5mm. In the latest sampled phases (TP and West mound) this range becomes much wider, with the largest ring width for *Celtis* deriving from TP samples (>7mm). *Ulmus* ring width measurements display a wider range in earlier phases (South K and L) with lower ring width 0.2-2mm and larger >3mm. After South M, while a separation in ring width distribution is still observed (suggesting the presence of years of growth release), ring width ranges become generally narrower. The most likely occurrences of growth release periods for *Ulmus* are observed in South K, L, M, P, TP and West mound assemblages. *Fraxinus* ring width (Fig. 5.61) lies in a narrower range (<2mm) until South Q; growth release periods are observed in South Q-R, coinciding with the largest diameter measurements and the highest abundance values for this taxon. In later phases (South S, T and West mound) when *Fraxinus* abundance starts decreasing again, ring width ranges also become narrower.

Ring width values for *Quercus* (Fig. 5.62) show a similar range to those of *Celtis* in earlier phases (e.g., South K, L). However, a majority of the measured *Quercus* rings are <1mm in much higher proportions compared to the other taxa included in the study. This might suggest the existence of an environmental driver (i.e., that *Quercus* trees and shrubs generally grew in drier habitats). However, *Quercus* wider ring width ranges are comparable to those observed for *Ulmus* and *Celtis* (1-1.5mm). A comparatively less pronounced separation in ring width distribution of *Quercus* is observed in South K, L, M, O, P, Q and possibly also in TP samples. The widest range for *Quercus* is observed in South P and South R, suggesting periods of growth release. Through time, the minimum ring width range for *Quercus* consistently increases; minimum ring width rises above 0.5mm after South O. After South Q, *Quercus* minimum ring width values are almost always above 0.5mm regardless of maximum ring width values. This suggests that deciduous oak growth conditions became more favourable (in terms of wood productivity) towards the later phases of Çatalhöyük. This gradual increase in the magnitude of growth release periods can be seen when ring width measurements of individual fragments are plotted (see Fig. 5.63). While an increase in ring width is visible in *Quercus* fragments from phases South K and L, the specimen from South P displays a more abrupt and higher magnitude increase, strongly characteristic of growth release periods in managed woodlands. A similar ring width pattern is observed in an *Ulmus* specimen from South L. Figures 5.21, 5.22 and 5.23 display similar growth release periods in individual fragments of *Quercus*, *Ulmus* and *Celtis*.

Lastly, a direct comparison of the results of the qualitative (curvature degree classes) and quantitative (minimum diameter and growth ring width estimations) methods assists the evaluation of the potential of the former for predicting the approximate size and calibre of the wood preserved as charcoal in the archaeological deposits. Figure 5.64 demonstrates that, despite the presence of outliers, there is a clear separation in the ranges of values represented by different curvature degree classes. Class 3 (strongly curved) covers approximately a minimum diameter range of 3.5 to 40mm (excluding outliers at 107mm and 184mm). There seems to be a wider range of measurements and more overlap between curvature degree classes 2 and 1. Class 2 represents a number of specimens ranging from 8mm to 189mm (excluding outliers 281mm, 219mm and 4mm) while class 1 covers a range from 14mm to 425mm. One of the possible explanations for this overlap in diameter sizes could have to do with the extremely narrow growth rings observed on some specimens, which could alter the growth ring morphology (and therefore the curvature of the growth ring) regardless of diameter. Overall, curvature degree classes appear to provide a useful blueprint for the study of large charcoal assemblages with relative ease and speed, and within an acceptable level of accuracy.

5.6 Multivariate analyses of quantitative and qualitative data

In order to achieve a more in-depth understanding of the patterns observed in the anthracological assemblage a number of multivariate statistical techniques were applied to the charcoal dataset. As outlined in section 5.1.2 per-sample taxon counts from all sites included in the study were investigated using Correspondence Analysis (CA). In addition, temporal and context-related variation in the Çatalhöyük assemblage was investigated further using the same technique. The dendroecological dataset was also further analysed using Multiple Correspondence Analysis (MCA) and CA in order to investigate the potential co-variation of dendroecological features and taxon representation. Finally, the Çatalhöyük charcoal dataset was analysed alongside the available dung-seed archaeobotanical and faunal datasets using Multiple Factor Analysis (MFA) in order to infer site-wide temporal patterning in subsistence practices and their impacts on the local fuel economy.

The results of CA applied on per-sample charcoal raw taxon counts (dispersed contexts, ‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) from all sites included in the present study are presented in Figure 5.65. The results of previous analyses by Asouti (2005, 2013) were incorporated into those of the present study, in order to investigate temporal and spatial patterning more fully in the dataset (including 178 samples). The first two dimensions account for 49% of the variation observed in the dataset (see also Fig. 5.65, Table 5.22a). A great proportion of the contribution to dimension 1 is by *Amygdalus, Quercus* and *Pistacia* along the axis that separates the majority of the Pınarbaşı samples (from all phases) from the Çatalhöyük and Boncuklu samples (Table 5.22b). A number of Pınarbaşı Epipalaeolithic samples cluster more closely with the later Çatalhöyük samples, which is mostly due to the prominence of *Juniperus* in these samples. The Can Hasan III samples are spread along dimension 1, between the *Amygdalus*-dominated Pınarbaşı samples and the Ulmaceae-dominated Çatalhöyük samples. The majority of the early and middle Çatalhöyük phases (South G(early)-P) are clustered at the bottom right hand-side of the plot with *Quercus*, Ulmaceae and Salicaceae (Fig. 5.65). On the opposite side of axis 2 the late phases

(South Q-T), and the TP and West mound samples are spread. On the whole, it appears that temporal patterning in the dataset is fairly well represented, explaining most of the variation observed in charcoal taxon counts.

When the per-sample counts from the Çatalhöyük dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) are evaluated more closely, the temporal element of the variation can be observed more clearly. The first two dimensions of the CA account for 54% of the variation in the dataset (including 113 samples) (Fig. 5.66, Table 5.23a). The main separation on opposite sides of axis 1 is again between *Juniperus* and *Quercus*-Ulmaceae-Salicaceae separating the earlier phases (South G(early)-P) from the later phases (South Q-T, TP and West mound). Along axis 2, with mostly *Quercus* and Ulmaceae contributing to the dimension (see also Table 5.23b) a further separation is visible between the earliest phase of occupation (South G(early)), which is confined to the upper left-hand side of the plot, and the later phases (South G(late)–H-P). The TP and West mound samples are also separated along axis 2 from the later part of the East mound sequence (South Q-T) due to the more prominent presence of Ulmaceae, *Pistacia* and *Amygdalus* in the TP and West mound samples. No apparent ecological separation can be detected, three of the four divisions containing a mixture of dry and wet woodland taxa. For instance, on the portion of the plot containing Ulmaceae and Salicaceae, *Artemisia* is also represented, while on the portion containing *Juniperus, Fraxinus* is also represented. In addition, taxa more characteristic of drier habitats such as *Pistacia* and *Amygdalus* are represented on the same part of the axis as *Tamarix*, a halophytic taxon typical of wetland edges. This situation possibly reflects long-lasting wood fuel use practices on site, which included a mixture of dry and wet woodland taxa. To investigate further this patterning, a CA on primary fuel waste debris deposits from all phases at Çatalhöyük was conducted. The first two dimensions of the CA biplot account for 56% of the variation observed in the assemblage (Fig. 5.67, Table 5.24a). A majority of this patterning is explained by the separation between *Juniperus-Fraxinus-Amygdalus* and the remaining taxa on opposite sides of axis 1. While no temporal patterning is evident, it appears that some external fire features contain a more diverse range of taxa (clustered on the upper right-hand side of the biplot). On the other hand, whether internal or external, fire features containing *Quercus* tend to be dominated by this taxon (clustered on the lower right-hand side of the plot). The majority of the contribution to the inertia in the dataset derives from

Juniperus and *Fraxinus* in dimension 1, and *Quercus* and Ulmaceae in dimension 2 (Table 5.24b). While in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), this separation was characterised by a strong temporal dimension, in primary fuel waste contexts it encompasses a mixture of phases and context types (i.e., internal and external fire spots). This situation might be explained as a result of different pyro-technological requirements, especially concerning the use of *Quercus* wood as fuel in particular fire features. Alternatively, it could signify distinct episodes of wood fuel collection. The inclusion of shrubby taxa in fire features comprising mostly Ulmaceae and Salicaceae may reflect expedient fuel gathering, whereas the use of *Juniperus*-*Fraxinus* or *Quercus* might signify the management of higher quality collected and stored fuel wood.

The Çatalhöyük charcoal taxon and dendroecological datasets collected by the present study were further investigated using MCA. All charcoal fragments on which dendroecological observations were made were included in the analysis as individual data points, while the presence/absence of dendroecological features were treated as categorical variables. The first two dimensions account for 24% of the variation observed in the dataset (Table 5.25a). The main factors are curvature degree, pith, bark, tyloses, trauma canals, fungal hyphae and false rings (Table 5.25b). The factor map (Fig. 5.68) reveals associations between the occurrence of some dendroecological features and taxon representation. Traumatic canals, false rings and reaction wood are closely associated with *Juniperus*. On the other hand, in the lower right hand-side of the biplot Curvature Degree 3 (strongly curved, smaller diameter), pith and bark are more closely associated with *Tamarix*, *Capparis*, Leguminosae, *Rhamnus*, Chenopodiaceae, *Artemisia*, Maloideae, Anacardiaceae, *Pistacia*, and *Amygdalus*, and some Salicaceae and Ulmaceae. Curvature Degree 1 co-occurs more closely with tyloses, fungal hyphae, collapsed vessels, mineral deposits and radial cracks. Although there is a high degree of clustering in the centre of the biplot *Quercus*, *Ulmus* and *Celtis* appear to be more closely associated with tyloses, fungal hyphae and collapsed vessels. There seems to be no significant difference in the range of dendroecological features observed in specimens derived from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) and fire features; both are plotted close to the origin. The second dimension of the MCA plot separates the specimens temporally, with the early-middle phases concentrated in the lower part of axis 2, and the later phases in its upper part.

The plot of individuals resulting from this MCA is presented in Figures 5.69 and 5.70. Individual specimens were coded according to phase and context type in order to evaluate the presence of temporal and/or context-related (spatial) patterning. Specimens appear to be characterised by similar dendroecological qualities regardless of context type, while phases are also more or less evenly represented in both axes. Figure 5.70 is a biplot of individuals from select taxa: although there is some overlap most *Juniperus* specimens are confined to the right-hand side of axis 1, while most *Quercus* fragments are spread on the left-hand side of axis 1. On the whole, dendroecological features appear to be more closely related to changes in taxon frequencies rather than context type or phase (see also Fig. 5.68).

In order to investigate the dendroecological composition of each sample, per-sample counts of dendrological features were converted into a data matrix comprising the sums of the observations recorded for each feature. The resulting 57 samples from midden and fire feature contexts were investigated using Multiple Factor Analysis (MFA). This technique allowed for the treatment of the two datasets (charcoal taxon counts and dendroecological features counts) as separate groups; thus inertia within groups could be calculated independently. The first two dimensions account for 65% of the variation observed in the dataset (Fig. 5.71, Tables 5.26a-d). The charcoal dataset and the dendroecological dataset contribute equal weights in dimension 1 (Table 5.26b). The main components of the dataset in dimension 1 are tyloses, fungal hyphae, Curvature Degree 3, *Juniperus* and *Quercus* and in dimension 2 Ulmaceae, *Quercus*, Curvature Degree 3 and pith. Confirming the results of MCA, variations in taxon abundance appear to be closely related to variations in the frequency of dendroecological features on a sample-by-sample basis (see also Fig. 5.72). Dimension 1 of the dendroecological dataset and dimension 1 of the charcoal taxon count dataset reflect inertia in the same direction, with a relatively narrow angle, thus suggesting a close relationship between the two datasets. Dimension 2 for both datasets is also closely correlated. The main variation in taxon composition is reflected in the nearly perfect inverse relationship between *Juniperus* and *Quercus*, predominantly along dimension 1 (see factor map in Fig. 5.71). On the other hand, the variation in the dendroecological dataset appears to be limited to the right-hand side of axis 1. The main significant components of dimensions 1 and 2 (Table 5.26d, Fig. 5.71) demonstrate that *Quercus* is more closely linked to Curvature Degree 1 and tyloses, while Salicaceae and *Ulmus* are associated with collapsed vessels, fungal hyphae and radial cracks. Ulmaceae and *Artemisia* appear to be more significantly related to pith and Curvature Degree 3.

The biplot of individual samples (Fig. 5.73) indicates that a distinction between midden and fire feature contexts can only be ascertained when charcoal taxon counts and dendroecological features are considered together. Dimension 1 accounts for 47% of the variation observed, which is directed mostly by temporal variation in the dominant taxa, thus confirming the results of the CA analyses discussed earlier (see also Figures 5.66, 5.67). The samples clustered on the lower left-hand side of the axis comprise South P and South Q fire features characterised by the presence of a low number of Curvature Degree 3 and a high number of Curvature Degree 1 specimens. Most midden samples contain a low number of Curvature Degree 1 specimens, regardless of taxon. 2 other fire features from South P are placed closer to South G(late)–H samples in the upper right hand-side of the biplot, containing a high number of Curvature Degree 3 specimens with pith and bark (twigs). Both sets of fire features represent external hearths; therefore their separation in two distinct groups is likely to reflect variability in fuel use practices rather than context-related (spatial) variation.

To explore further any latent patterning in fuel use practices involving wood and dung fuel MFA was used treating charcoal taxon counts and dung-derived non-crop seed counts as two different groups due to their distinct taphonomic pathways. The dataset consists of 30 samples (fire features and primary fuel waste deposits) from which wood charcoal counts and dung-seed counts are available (the dung-seed data were derived from Fairbairn et al. 2005, Bogaard et al. 2013, 2014a, Filipović 2014). The classification of wild/weedy taxa as dung-derived follows Bogaard et al. (2013, 2014a) and Filipović (2014) (see Table 5.1 for a list of dung-derived taxa and their corresponding habitats). MFA results are presented in Tables 5.27a-d and Figures 5.74-5.77. The first two dimensions account for 59% of the variation observed in the dataset, with dung-seed data and wood charcoal data contributing equally to the first dimension. Inertia in dimension 1 is explained by a weak inverse relationship between the charcoal dataset and the dung-seed dataset, which are placed on opposite sides of axis 1 (Fig. 5.74). In dimension 2 the dung-seed dataset contributes considerably less to variation and common inertia; thus the nature of the relationship between the datasets cannot be interpreted with certainty. A closer inspection of the individual taxa included in each group (Fig. 5.75, Table 5.27c) reveals that the main drivers of the dung-seed dataset are *Bolboschoenus glaucus* and *Beta*, which are placed a weakly inverse position to *Juniperus* and *Fraxinus* of the wood charcoal dataset. A majority of the prominent dung-derived seed taxa are clustered together with *Quercus* (Figure 5.75). As the biplot of individuals in Figure 5.76 demonstrates, a majority of the internal fire features are clustered in the lower left hand-side part of the plot, due to the lower number of dung-derived seed taxa in these contexts. External fire features from earlier phases contain more *Bolboschoenus glaucus* compared to external fire features from later phases (South Q, S) (see also Fig. 5.77). This patterning in the presence of dung-derived seed remains resonates with previous analyses conducted by Bogaard et al. (2014a) which showed that dung fuel was more likely to be used in external fire features, and present in internal fire features in much lower proportions. Although the number of samples analysed with MFA is low, the dataset indicates the association of wetland-derived dung seeds with *Quercus* charcoal in external fires. At the same time, the great degree of variability observed in the composition of wood and dung fuel remains within the same phase and in similar context types might reflect the variable nature of different fuel use episodes and taphonomic processes affecting the preservation of carbonised plant remains.

MFA analysis was also applied to dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) for which wood charcoal taxon counts and dung-seed counts were available (33 samples from phases South G(early)-S). The results (Figures 5.78- 5.80, Tables 5.28a-d) point to a somewhat different pattern when compared to primary fuel waste deposits. Dung-seed taxa contribute most of the inertia in dimension 1, whereas in dimension 2 a majority of the variation is accounted by the wood charcoal dataset (see Table 5.27b). The first two dimensions account for 79% of the variation observed in the dataset; dimension 1 of the wood charcoal and dung seed datasets is very weakly related (Fig. 5.78). The factor map of variables demonstrates that this is driven mostly by *Bolboschoenus glaucus* and small-seeded legumes (Leguminosae) (see Fig. 5.79, Table 5.28c). Variation in the abundance of Ulmaceae appears to be weakly tied to *Bolboschoenus* and Leguminosae on dimension 1. *Quercus* and *Juniperus* are inversely related and are mostly unrelated to the dung-seed taxa. The individual sample biplot (Fig. 5.80) indicates a temporal separation in the prominence of wood charcoal and dung-seed taxa. On the right-hand side of the plot are clustered samples dominated by dung-seed taxa (especially *Bolboschoenus glaucus* and *Aeluropus*) and Ulmaceae charcoal. Samples containing lower numbers of dung-seed taxa and higher counts of *Juniperus* are clustered in the lower left-hand side of the biplot. Samples with moderate frequencies of dung-seed taxa and *Quercus* are contained in the upper left-hand side of the plot.

In order to investigate further these patterns in the preference for particular wood fuel taxa through time and in the presence of dung-seed taxa, a more robust analysis was carried out on the per-phase dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) sums of the two groups alongside a select portion of the faunal dataset comprising some of the herded and hunted species (*Bos, Ovis, Capra,* cervids, equids and *Sus*) (Table 5.29). Evaluating these datasets on a per-phase basis permitted overcoming problems arising from the low number of contexts from which suitable records for all three data categories (charcoal, seed, faunal) are available. MFA results are presented in Figures 5.81-5.83 and Tables 5.30a-d. The first two dimensions account for 72% of the observed variation, with faunal and charcoal datasets contributing to the majority of the inertia in dimension 1, and dung-seed and charcoal datasets contributing mostly to the inertia in dimension 2 (Table 5.30b, Fig. 5.81). The factor map of variables (Fig. 5.82) indicates that, similarly to the analysis of individual midden samples, *Bolboschoenus glaucus*, Leguminosae (small-seeded legumes) and *Heliotropium* are tied to Ulmaceae. These taxa are in a weak inverse relationship to *Quercus* along dimension 2. *Juniperus*, *Fraxinus* and *Amygdalus* (all prominent in the later phases) are in a close positive relationship to caprines (*Ovis*, *Capra*, and *Ovis*/*Capra*) alongside the dung-derived chenopod *Suaeda*. The contributions and p-values of *Equus*, equids and cervids do not appear to be significant (see Tables 5.30c-d). However, it should be noted that on the whole some of the wild fauna (e.g., equids and cervids) appears more prominently in phases registering a higher abundance of *Quercus*. The plot of the individual phases (Fig. 5.83) displays some of these temporal patterns more clearly. It shows the placement of the means for each phase (in black), the placement for each phase of the dung-seed dataset (in red, connected with a red line to the mean), the faunal dataset (in green, connected with a green line to the mean) and the charcoal dataset (in blue, connected with a blue line to the mean). South G(early) stands out with its distinctive composition of dung-seed and wood charcoal taxa (being rich in wetland-derived seeds and Ulmaceae) while dung-seed taxa for all other phases are clustered in the lower left hand-side of the biplot. Separation of the earlier (South G(late)–H to South P) from the later (South Q-T) phases is defined mostly by the charcoal and faunal composition. Interestingly, South T is placed on the upper right hand-side of the biplot, as a result of its higher values of dung-seed taxa compared to earlier phases (including non-weedy graze sources such as *Sporobolus*, *Crypsis* and *Bolboschoenus*).

5.7 Summary

The results presented here provide a detailed anthracological sequence for prehistoric south-central Anatolia. As expected, smaller and/or less sedentary occupations contain lower charcoal densities, possibly reflecting lower frequency of fuelwood use compared to more sedentary, larger agropastoral settlements. In all sites, the use of deadwood is very well documented. In addition, site-specific preferences for certain taxa are evident both in the results of descriptive and exploratory multivariate analysis, such as the predominant use of *Amygdalus* at Pınarbaşı and Salicaceae at Boncuklu. Riparian and/or wet woodland taxa form important elements of the fuel wood assemblage for a significant part of the early-mid Holocene sequences (i.e., Boncuklu, Can Hasan III, Çatalhöyük East and West mound). During the early phases of occupation at Çatalhöyük East, *Quercus* wood charcoal values increase in parallel with increasing *Quercus* pollen in the regional off-site palaeoecological spectra (see Chapter 2). As demonstrated by the results of multivariate analyses, shifts in the fuel economy of Çatalhöyük East and West mounds coincide with shifts in practices in other subsistence-related and routine activities (e.g., herding and hunting) and may be reflecting shifts in socio-economic organisation or changes in the scheduling of seasonal and/or routine activities in the landscape. In fact, temporal patterning in the wood charcoal assemblage is not divided solely along an environmental gradient, but rather reflects a stronger temporal trend. These patterns in sample composition reflect the continued use of riparian and semi-arid woodlands in distinct combinations through time, supplemented by the use of dung fuel. *Juniperus* remains, present in south-central Anatolia from the earliest phases of occupation at Pınarbaşı following glacial retreat, display narrow growth rings, traumatic canals and other ring deformities suggesting that this taxon was under some degree of ecological stress. Findings of the frequent presence of tyloses and larger diameter specimens of *Quercus* support the possible harvesting of trunk wood for use as fuel. The results of minimum diameter estimations and ring width measurements demonstrate the possible wood anatomical signatures of management activities and/or controlled cutting cycles in both semi-arid and riparian woodlands during the occupation of Çatalhöyük. Overall the results of the present study confirm Chabal's observations with regard to charcoal fragmentation (i.e., irrespective of taxon, charcoal densities and fragment counts correlate). In addition to this, it was demonstrated that burning introduces a significant taphonomic filter in the preservation of sapwood. For this reason, smaller calibre portions of fuel wood appear to be universally over-represented (*contra* Dufraisse 2008). In Chapter 6, these results and their implications will be discussed with regard to prehistoric woodland ecologies in south-central Anatolia, the fuel economies of the sites included in this study, and human impacts on the landscape.

CHAPTER 6: DISCUSSION

The principal aims of the present study are (a) to investigate and characterise fuel wood selection and use practices, including their cultural and ecological dimensions, (b) to investigate the range, scale and temporal patterning of human impacts on woodland vegetation in south-central Anatolia during the early to mid-Holocene, and (c) to evaluate the representativeness of anthracological remains of fuel wood use for reconstructing vegetation ecologies and changes in the form and structure of woodlands. In the context of this project's research questions (outlined in Chapter 1) a systematic study of dispersed (*'charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) and primary fuel waste contexts was conducted comprising anthracological assemblages from four prehistoric habitation sites located in the Konya plain of south-central Anatolia: Pınarbaşı (Epipalaeolithic, early-late Neolithic, Chalcolithic), Boncuklu (aceramic Neolithic), Can Hasan III (aceramic Neolithic), Çatalhöyük East (aceramic to late Neolithic) and Çatalhöyük West (Chalcolithic). Together these sites span the period ~15 ka-7.5 ka cal. BP.

A total of 6072 fragments of wood charcoal was identified by the present study to family or genus level. All of the identified fragments (3712; representing wood charcoals identified only in the present study) from the Çatalhöyük East and West mound assemblages were also examined for recording the presence of dendroecological anatomical features including tyloses, fungal hyphae, resin canals, gum ducts, callus/scar tissue, boreholes, collapsed vessels (tracheids in conifers), narrow growth rings, false growth rings, tension wood, radial cracks and mineral deposits. In addition, qualitative calibre classification was applied resulting in 2227 fragments with recorded curvature degree classes (following the methodology of Marguerie and Hunot 2007; see also Chapter 5, section 5.4). Quantitative diameter estimation methods (including minimum estimated diameter and the sequential measurement of growth ring width) were applied to 182 charcoal specimens from Çatalhöyük (following the adjusted methodology of Paradis et al. 2013; see also Chapter 5, section 5.5). The results of quantitative and qualitative analyses were further investigated using a suite of descriptive and exploratory multivariate statistical techniques (see also Chapter 5, section 5.1.2, 5.6). Per-sample charcoal taxon counts from all sites included in this study were explored using CA. The dendroecological dataset was explored using MCA, focusing on the co-occurrence of individual features. The per-sample charcoal taxon counts and dendroecological datasets were analysed jointly using MFA. Finally, per-phase charcoal taxon counts were analysed using MFA jointly with datasets derived from dung-derived non-crop seed counts and NISPs of select herded and hunted faunal taxa from the same phases.

In the context of anthracological research in Southwest Asia, the present study represents the first instance of the systematic application of dendroecological analyses on wood fuel remains. A range of qualitative and quantitative methodologies developed in the last decade primarily by French researchers were applied on the exceptionally well-preserved anthracological assemblage of Çatalhöyük. The remarkable, by Near Eastern standards, preservation of the Çatalhöyük wood charcoals alongside the long anthracological sequence available from this site, provided a first-rate opportunity for assessing the practicality and viability of these methods on fuel wood debris deriving from early-mid Holocene sites, and their utility for reconstructing local vegetation ecologies and the woodland management strategies of early agricultural societies in Southwest Asia. More specifically, in the context of existing palynological and palaeoclimatic records (reviewed in Chapter 2), the findings of the present study can be assessed with regard to: (a) the representativeness of charred wood fuel waste remains for reconstructing early to mid-Holocene vegetation catchments, and (b) the insights they can provide for understanding the combined effects of climate change and human impacts on local and regional vegetation dynamics during the establishment phase of early agricultural economies.

The results of the present study are discussed in the remainder of this chapter. First the implications of the present study for assessing and expanding on currently dominant methodological and theoretical paradigms in the field of anthracology are explored. This element of the discussion focuses on a constructive critique of current approaches, while also specifying the distinctive contributions of the present study to the development of novel analytical and theoretical tools for understanding wood charcoal taphonomy, and for interpreting prehistoric fuel use and woodland vegetation ecologies and management strategies. A particular focus is placed on examining the representativeness of anthracological assemblages for reconstructing prehistoric woodland vegetation dynamics. Following this, the contributions of the present study are evaluated with regard to reconstructing past vegetation, human impacts and woodland ecologies and management practices in prehistoric south-central Anatolia. The chapter concludes with an evaluation of these results set in the broader context of anthracological studies in Southwest Asia.

6.1 Charcoal taphonomy in context

As discussed in Chapter 4, an important element of anthracological analyses is the detailed evaluation of the taphonomic status of an archaeological wood charcoal assemblage, in order to establish its representativeness with regard to the relative proportions and intensity of use of wood fuel taxa in the past. In the context of the present study, this aspect was central to the assessment of the representativeness of the anthracological assemblages for reconstructing prehistoric woodland composition and ecology, and woodland management practices, in the Konya plain and its environs. In the present study, density values (grams of charcoal per litre of sediment) were calculated for the Pınarbaşı, Boncuklu and Çatalhöyük assemblages in order to assess the nature of fuel waste debris deposition, by comparing density distribution patterns across primary and dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999). As described in Chapter 5 (section 5.2) all sites contained a majority of contexts with average to below-average charcoal density values (average values were calculated separately for each site). At all three sites a minority of contexts contained significantly above-average charcoal densities. This distribution pattern, expressed as a left-skewed density plot, was observed for both dispersed (secondary, (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999)) and primary fuel waste deposits. These observations are in agreement with hypotheses previously put forward by Chabal (1992, 1997) and Chabal et al. (1999) regarding wood charcoal preservation in archaeological contexts (see also Chapter 4, section 4.1). Furthermore, the same density distribution pattern was observed at Pınarbaşı and Boncuklu, which were characterised by low average and median wood charcoal density values, and at Çatalhöyük, which was characterised by comparatively much higher values. This suggests that habitation type (e.g., sedentary vs. mobile), length of occupation, and population size are largely unrelated to the spatial (intra-site) distribution of archaeological charcoal density values. Chabal et al. (1999) had proposed that this pattern (applicable to the spatial distribution of both charcoal fragment counts and weights) reflects a Poisson distribution. The implication is that across space and time burning, depositional and post-depositional taphonomic events comprise rare events that are characterised by high-density deposition and fast burial of charcoal, and more frequent events that are characterised by average to below-average rates of charcoal deposition. This in effect represents the main plausible cause of the left-skewed density distribution of charred wood fuel remains.

Taxon representativeness, on the other hand, is unaffected by overall charcoal density distributions. The main determinants are, instead, context type and the duration of the activities represented in the archaeological record (e.g., long-term charcoal deposition in midden contexts). Thus, while charcoal density distributions were similar in dispersed (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) and primary contexts, differences were noted in charcoal sample composition and diversity. In general, dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) contained a more diverse range of taxa, while primary ones contained far fewer taxa (see also Chapter 5, section 5.2). These findings support the propositions by Chabal et al. (1999) and Asouti and Austin (2005) that dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) are more likely to contain the accumulated remains of multiple episodes of fuel waste disposal, thus resulting in taxonomically more diverse assemblages (Chapter 4; see also Table 4.1). Finally, assemblage representativeness was evaluated by assessing on a sample-by-sample basis the overall consistency in the relative proportions of the different charcoal taxa for each sampled phase. Individual charcoal taxon frequencies (percentage fragment counts and ubiquity scores) were found to be overall consistent between dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) from each phase; they are thus likely to represent the relative proportions and frequency of use of fuel wood taxa within each phase.

The distribution of diameter size-classes and curvature degree classes were examined for each taxon and across phases (Chapter 5, sections 5.4, 5.5). Contrary to the hypothetical distribution pattern proposed by Dufraisse (2008; see also Fig. 4.8) the distribution of diameter size-classes was found to conform to a lognormal distribution (see Figures 5.45, 5.48). Lognormal distribution of diameter size-classes at Çatalhöyük was replicated for each taxon and has been observed in all sampled phases, for both primary and secondary fuel waste deposits (see also Fig. 5.45). Regardless of taxon and context type, diameter size-classes are always represented with a high number of small diameter specimens and a low number of large diameter specimens. The same pattern was observed with regard to the distribution of curvature degree classes (which included a much higher number of observations): a majority of fragments were classified as Curvature Degree (CD) 2 and 3 (moderately and strongly curved rings) while only a minority of fragments were classified as CD 1 (low curvature) (see also Figures 5.42-5.43).

The abundance of tyloses in some taxa (interpreted as signifiers of the presence of heartwood) has provided additional insights regarding the ubiquity of mature stem wood in the Çatalhöyük anthracological assemblage. As described in Chapter 5 (section 5.4) tyloses represent the qualitative dendroecological feature most commonly recorded in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) as well as *in situ* fuel waste deposits (see Table 5.17). The majority of the wood charcoal fragments of angiosperms (e.g., *Quercus*, Ulmaceae) included tyloses and are thus likely to represent heartwood. More rarely, the transition from heartwood to sapwood and/or sapwood per se were also preserved (see Fig. 5.16). Furthermore, as indicated by the MCA of the per-specimen observations of dendroecological features, a close association exists between CD 1, the presence of tyloses and *Quercus* (see Chapter 5, section 5.6, Fig. 5.67). Patterning in the data was also detected by MFA run on charcoal taxon counts and the per-sample counts of the presence of individual dendrological features (Fig. 5.70). Most of the *Quercus* fragments for which CD classes could be determined were classified as CD 2 and 3. However, the association of CD 1 with *Quercus* indicates that when low ring curvature is observed, this is most likely to occur in *Quercus* fragments. The same applies to the presence of tyloses, which further supports the possibility that a majority of the *Quercus* fragments preserved at Çatalhöyük represent heartwood remains. The logical conclusion following from these observations is that sapwood parts (and, by implication, the larger diameter portions of the logs originally put into fire) are consistently under-represented in the anthracological assemblage. Conversely, smaller diameter portions of fuel wood are consistently over-represented, most likely due to the complete combustion of sapwood during burning. For this reason, the diameter size-classes represented in the anthracological assemblage are skewed towards the preservation of the smaller diameter portions of fuel wood. They are thus unlikely to represent per se a reliable estimation of the original calibre and volume of the logs harvested and used as fuel wood.

These results and interpretations could be further tested by future experimental work in order to evaluate more precisely the preservation potential of different diameter size-classes. Nevertheless, an important implication of the present study is that the hypothesis that the diameter size-classes represented in a given anthracological assemblage are proportional to the calibre and volume of the logs collected and used as fuel wood in the past is not upheld (cf. Dufraisse 2008). More generally, as highlighted by Limpert et al. (2001) lognormal distributions are characteristic of a vast array of biological processes including species abundance distributions, inheritance of fruit and flower size, the concentration of elements in the Earth’s crust and their rates of degradation, species survival rates, lengths of dormancy of communicable diseases, and many others. As these authors have suggested, the underlying causes of lognormal distributions are the multiplicative effects of taphonomic processes that determine them. In the case of charcoal diameter size-classes, a lognormal distribution likely highlights the multiplied effects of mass loss during carbonisation, fragmentation during and after burning, and the complete combustion of the larger diameter portions (i.e., the outer portions situated closer to the periphery of the log) of the wood logs burnt in a fire.

6.2 Modelling prehistoric fuel wood economies and their ecological impacts on the basis of anthracological data

As discussed in Chapter 4 (see Section 4.2), there are two main schools of thought concerning the interpretation of anthracological results. The more prominent of the two concerns theoretical models inspired from the Principle of Least Effort (PLE) and focuses primarily on the inferences that can be drawn from anthracological assemblages for reconstructing woodland composition and past vegetation cover. PLE’s premises hypothesise that under conditions of low woodland density, (density being determined by population size, i.e. per capita wood fuel requirements, rather than the ecological properties of woodlands per se) prehistoric fuel wood economies will be *non-selective* in their harvesting and use of fuel wood species. By contrast, selective fuel economies will emerge under conditions of high woodland density (see also Shackleton and Prins

1992; Chapter 4, Table 4.2). An important implication of this kind of reasoning is that, in order for anthracological analyses to provide meaningful characterisations of local fuel economies and reliable reconstructions of past vegetation, it is necessary to cross-check their results by comparison to information available through other sources of palaeovegetation evidence (namely pollen and anthracological spectra derived from other sites of the same period and geographical region) (cf. Chabal et al. 1999). These can be used to verify whether the dominance of a particular taxon or group of taxa observed in a given anthracological assemblage is a "true" reflection of its availability in past vegetation and (by implication) of its selective/non-selective use in the local fuel economy. While on first appearance PLE models would seem to provide a rational explanatory framework of the balance between woodland resource availability and use, their simplicity proves rather deceptive when considering the full range of the available ethnographic and archaeological case studies pointing to the multitude of ecological, cultural and socioeconomic situations that determine wood fuel availability and selection (see overview and discussion in Chapter 4, section 4.2). The most important shortcoming of PLE approaches lies in the fact that (by focusing predominantly on floristic composition and predicted levels of fuel consumption) they fail to take proper account of the ecological properties of woodlands: namely the density, form, habit and structure of woodland stands. Table 6.1 displays a slightly modified version of the PLE, which draws attention to the range of possible effects of such ecological properties on fuel wood collection. Given different levels of woodland density and diversity (and any combinations thereof) PLE-derived scenarios of wood fuel use invariably predict anthracological assemblages that consist of a very narrow range of taxa. It is only under conditions of high-diversity and low-density stands, located in the immediate vicinity of the settlement, that one might expect the "true" nature of local woodland composition to be reflected in the anthracological assemblage.

On the other hand, the heuristic model of wood fuel selection proposed by Asouti and Austin (2005) predicts that fuel wood collection is predicated on the overarching subsistence economy mode and the mobility strategies practiced by individual social groups (e.g., mobile hunter-gatherer, pastoral nomad and settled agro-pastoral societies; see also Table 6.2) that shape decision-making and determine the subsistence-related tasks into which fuel wood procurement is integrated. These authors hypothesised that fuel wood collection by more mobile groups is likely to be opportunistic in nature, thus resulting in a predictive scenario compatible with the non-selective fuel economies proposed by the PLE. Drawing on a substantial body of ethnographic literature Asouti and Austin (2005) argued that in settled agro-pastoral societies, practicing multi-layered subsistence economies, fuel wood collection is imbedded into complex routines of other subsistence-related tasks (cultivation, herding, timber and fruit crop management, etc.) which will result in cycles of selective and non-selective collection and use of fuel wood at variable catchments. They thus concluded that patterns of fuel wood collection and use by agro-pastoral societies are determined by a complex network of socio-economic, cultural and ecological parameters including ease of collection, technology of fuel wood harvesting, resource ownership, access to woodland resources and socio-cultural perceptions of the environment (see also Picornell et al. 2011 for a more recent ethnographic case study).

A shared characteristic of both the classic PLE models of fuel wood selection and the distinctly “socio-economic” paradigm proposed by Asouti and Austin (2005) is their attempt to model predictive scenarios of fuel wood selection based on the overarching societal factors (population size and economic organisation respectively) that shape collection strategies. Neither approach attempts to model in a more systematic manner the ecological dimension of wood fuel collection as a distinct form of people-environment interactions. As a result, the feedback cycles between fuel wood collection and the vegetation dynamics arising from human impacts are not properly operationalized.

The key theoretical premise proposed by the present study is that regardless of the underlying socio-economic environments and associated decision-making processes, anthracological remains (as the material residues of the intentional use of wood as fuel) by proxy reflect the nature, degree and diversity of human impacts (negative or positive) on past vegetation. An accumulated body of ethnographic and anthropological case studies suggest that selective and non-selective fuel wood collection strategies may be practised by communities operating within widely differing socio-economic milieux and cultural traditions (see also Chapter 4, section 4.2). Thus wood fuel collection strategies can be selective, non-selective or both, largely independently of woodland availability, climate and environmental conditions, and/or energy needs. As concluded by Asouti and Austin (2005) properly recorded archaeological wood charcoal spectra represent an accurate reflection of the relative proportions of wood fuel taxa used in the past, and of the intensity of use of the different vegetation catchments from which they were sourced. For arid and semi-arid environments in particular, the utility of well-dated archaeological charcoal sequences for reconstructing woodland composition and the spatial distribution of prehistoric woodland catchments is further emphasised by the preservation limitations of off-site pollen sequences. However, the full interpretative potential of anthracological assemblages as the material residues of people-environment interaction lies in the fact that carbonised wood fuel remains embody the ecological signatures (i.e., the growth conditions and life histories) of the individual trees and shrubs collected as fuel, and of the woodland ecologies they have derived from. Thus, not only taxon presence and frequencies but also the form, function and environmental attributes of woodland growth conditions, and the ways in which they were impacted by woodland management activities, can also be recorded through the analysis of the dendroecological features. Anthracology provides a unique set of analytical tools with which to disentangle the varied phases of the complex feedback cycles between vegetation, climate conditions and prehistoric woodland management and landscape use practices. In this sense archaeological wood fuel remains represent a category of archaeobotanical data that are exceptionally well suited for reconstructing the origin and long-term histories of intentionally modified, anthropogenic landscapes. This point is further explored below in the context of the discussion of the results of the present study with regard to reconstructing prehistoric woodland ecologies and management strategies in the Konya plain during the early to mid-Holocene (sections 6.4.2.2-6.4.2.4).

6.3 Overarching patterns of fuel wood selection and use in the Konya plain

In the present study, the temporality of fuel use practices was evaluated by taking into account changes in the charcoal sample composition of dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) through time, as they are more likely to represent long-lasting patterns of fuel wood selection and use (see also Chapter 4, section 4.1). Space- or context-related variation (e.g., internal vs. external fire features) was evaluated through the examination of primary fuel waste sample composition. As described in Chapter 5, the strongest patterning in fuel wood use derived from temporal shifts in the representation of individual taxa. This is evident in the evaluation of the per-phase relative proportions of wood charcoal taxa (see Figures

5.40-5.41) also supported by the results of multivariate statistics run on the per-sample charcoal taxon counts (Figures 5.64-5.65). For all phases included in the present study there is a narrow range of ubiquitous taxa that dominates sample composition. That is, regardless of diversity, a small number of taxa dominate the wood charcoal assemblage of each phase. *Amygdalus* dominates the assemblages derived from all phases sampled at Pınarbaşı, Salicaceae dominate the Boncuklu assemblage, *Amygdalus* and Ulmaceae are equally abundant at Can Hasan III, while Ulmaceae are dominant in the earliest phase of Çatalhöyük (East mound; South G (early)). The midden samples from the remaining early-mid phases of Çatalhöyük (East mound; South G (late)–H to P) are dominated by *Quercus*. South Q-T is dominated by *Juniperus*, TP by Ulmaceae, while *Juniperus* is once more dominant in the West mound assemblage.

The anthracological assemblage from Pınarbaşı (all phases) differs substantially from the Boncuklu, Çatalhöyük and Can Hasan III assemblages. The core of this separation, also seen in the CA plot of charcoal sample composition for all sites (Fig. 5.64) lies in the enduring exploitation of *Amygdalus*-dominated woodland vegetation, which persists through time at Pınarbaşı. Another distinctive feature of the Pınarbaşı assemblage is the very narrow range of the taxa exploited as fuel: the presence and abundance of riparian taxa is extremely low despite the location of the site next to the Hotamış Gölü wetland. One possible interpretation of this pattern is that wetland arboreal habitats were very sparse and/or characterised by low deadwood productivity. If deadwood productivity was a decisive criterion of diachronic fuel wood selection at Pınarbaşı, assuming that *Amygdalus*-dominated semi-arid open woodlands provided readily available supplies of dry deadwood, then this might explain the enduring abundance of *Amygdalus* charcoal in the anthracological assemblage, alongside the superior burning qualities of almond wood compared to other taxa (cf. Asouti 2003a, Asouti and Austin 2005).

Deadwood is regularly present not only at Çatalhöyük, from where detailed dendroecological data are available, but also at Pınarbaşı, Boncuklu and Can Hasan III. This suggests a distinctive preference for the collection of dry deadwood as fuel, while also pointing to the relatively high deadwood productivity of the Konya plain semi-arid and riparian woodlands. Another possibility is that woodcutting took place off-site well in advance of fuel wood collection and transportation back to the settlement, thus allowing logs to dry in situ (hence also facilitating their exposure to fungal and insect infestation). Such practices might account for the absence of evidence for substantial on-site fuel wood storage, although such storage could also have been located on the settlement edges. Collecting and transporting dry timber and fuel wood would have been considerably less labour-demanding: seasoned trunks and logs would have been much lighter thus discounting some of the perceived costs associated with transporting wood over longer distances (i.e., beyond a 3-5 km radius around habitation sites).

Contrasting to Pınarbaşı, the rest of the sampled sites comprise a mixture of taxa originating in spatially and ecologically distinct vegetation catchments. That is, the main components of the fuel economies of each site are not limited to a single ecological zone. For instance, at Boncuklu and Can Hasan III dominant riparian taxa (Salicaceae and Ulmaceae respectively) are supplemented by dryland taxa (e.g., *Amygdalus* and *Pistacia*) that are ubiquitous if not always abundant. At Çatalhöyük (Chapter 5, sections 5.2 and 5.3) the dominant dryland taxa (*Quercus* and *Juniperus*) are accompanied in all phases of occupation by riparian taxa (Ulmaceae, Salicaceae and *Fraxinus*). This pattern of fuel wood use points to the continuous exploitation of distinct ecological zones in the Konya plain during the early to mid-Holocene, and could be indicative of certain cultural continuities in fuel wood use that transcended the micro-ecological diversity characterising the environs of each site. The likelihood of the existence of cultural and historical ties between the various early Holocene occupation phases at Pınarbaşı and other settlements in the Konya plain (Boncuklu and Çatalhöyük) and between Boncuklu Can Hasan III and Çatalhöyük has already been highlighted by studies of their archaeological attributes (cf. Carter et al. 2005, Baird 2005, 2012a).

Anthracological assemblages derived from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) likely reflect the combined residues of a number of distinct wood fuel burning events. It could thus be counter-argued that taxa derived from different ecological zones which are found in dispersed contexts might have entered the anthracological record as a result of distinct burning events, separated in time. However, such an interpretation is not supported by the evidence available from primary fuel waste contexts (see also Tables 5.8, 5.11). Several primary contexts at Boncuklu and Çatalhöyük contain charcoals of dryland taxa (e.g., *Quercus*, *Juniperus*, etc.) co-occurring with riparian taxa (e.g., Salicaceae, Ulmaceae). They are thus likely to have entered the record as part of the same burning events. In turn, this observation strengthens an interpretation suggesting that fuel wood collection activities took place simultaneously in distinct ecological zones, possibly involving annually/seasonally organized cycles of collection in vegetation catchments located at varying distances from habitation sites.

Furthermore, the charcoal sample composition of some primary contexts shows that certain burning events are entirely dominated by taxa found in much lower frequencies in dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) samples from the same phases (see Table 5.11). CA run on charcoal taxon counts from primary contexts at Çatalhöyük (Fig. 5.67) clearly displays the variability observed in the sample composition of primary fuel waste contexts belonging to the same phase. This variability does not seem to correlate with the location of the fire feature (i.e., external or internal). A larger dataset from primary fuel waste contexts might shed more light on the nature of this variability, especially if sampling can be extended to include the (currently under-represented) earlier phases of the site. However, based on the existing dataset, it can be assumed that the representation of rare taxa in each sampled phase might reflect wood fuel taxa that were used very infrequently and/or in very low proportions.

The analysis of primary fuel waste contexts provides additional insights into potential functional differentiation in fuel use. For example, it has revealed that, when present in fire features, *Quercus* tends to be dominant regardless of the location (internal or external) of the fire feature (see Fig. 5.66). The MFA of charcoal taxon counts and dung-seed counts also indicates a close association between *Quercus* and dung-seed taxa, especially in external fire features (see Fig. 5.74). Analyses by Bogaard et al. (2013, 2014a) and Filipović (2014) report a higher incidence and abundance of dung-seed taxa and charred dung pellets in external areas, especially in external fire features. The use of *Quercus*, a high-quality wood fuel alongside dung fuel might thus suggest the use of specific fuel recipes associated with particular outdoor activities. Phytolith analyses by Ryan (2013) of primary fuel waste deposits at Çatalhöyük also point to the frequent inclusion of various grass fuel sources, especially in outdoor fires, including *Phragmites*, Cyperaceae and other grasses. The combined use of high-quality oak wood fuel alongside dung and herbaceous fuel might be related to the firing of ceramics in outdoor shallow pits, as suggested by micromorphological analyses of external burning deposits (Shillito et al. 2013). Comparable practices are reported in the ethnographic literature (see also Chapter 4, section 4.2).

6.4 Temporal trends in vegetation change, fuel wood collection, human impacts and woodland management practices

6.4.1 The environmental setting

As discussed in Chapter 2, the timespan covered by the sites included in the present study (~15-7.5 ka cal. BP) reflects three periods of abrupt climate change (see also Table 2.1) the first of which represents the onset of warmer and wetter conditions ~14.7-12.65 ka cal. BP (GI-1) coinciding with the Epipalaeolithic occupation of the Pınarbaşı rock shelter. The earliest part of the GS-1 cold and arid period (~12.65-11.5 ka cal. BP) might have overlapped with the later phase of the Epipalaeolithic occupation at the site (Baird et al. 2013). The rest of the sites studied in the present thesis span the early to mid-Holocene. Beginning at ~11.5 ka cal. BP, the onset of the Holocene was marked by climatic amelioration including a rapid increase in temperature and precipitation. The earlier part of the Holocene is attested at the Pınarbaşı aceramic Neolithic occupation, while the occupation of Boncuklu, Can Hasan III and Çatalhöyük (East and West mounds) spans the early to mid-Holocene. As reviewed in Chapter 2 (section 2.4) in addition to shifts in climatic conditions the period covered by the present study also witnessed important shifts in vegetation cover and composition, both locally and across Southwest Asia. The available evidence suggests that changes in vegetation and climate were asynchronous, as the responses of woodland vegetation to climate change were gradual and far more complex than assumed by simplistic linear models of environmental change.

As outlined in the discussion of the modern and prehistoric vegetation ecology of south-central Anatolia (Chapter 2, Section 2.4.3) during the late Pleistocene and the early Holocene the Konya plain encompassed a diverse landscape dominated by marl steppe that was interspersed with a wide range of wetland habitats including shallow (seasonally flooded) lakes, marshes, saline basins, karstic sinkholes, and alluvial floodplains and fans. Riparian woodlands could have grown at the edges of seasonally flooded wetlands and marshes, along seasonal and permanent watercourses, and on the alluvial floodplains and fans accumulated on the Konya plain from inflowing rivers and streams. They included taxa such as Salicaceae, Ulmaceae, *Fraxinus*, Tamarix and Chenopodiaceae. On the edges of saline wetlands, in the marl steppe-wetland ecotones, and in steppe proper, a range of other shrubs and herbs could have abounded including

Artemisia, Chenopodiaceae, *Capparis*, Labiatae and Leguminosae. *Amygdalus, Pistacia* and Maloideae could have formed, along with *Celtis* and other Rosaceae, part of sparsely wooded semi-arid grasslands on the lower Taurus foothill zone, the colluvial and volcanic slopes surrounding the Konya plain, as well as the steppe-alluvium ecotones. On the other hand, given their rainfall and soil requirements, *Quercus* and *Juniperus* semi-arid mixed woodlands were likely limited to better-drained red-brown soils, clayey loams, the limestone terraces, volcanic colluvia, bajadas and metamorphic limestone uplands found on the low- to mid-elevation slopes surrounding the Konya plain (Figures 2.5 and 2.8). Thus such mixed woodlands might have been better developed along the southern edges of the Konya plain grading into the Taurus foothill zone.

6.4.2 Fuel wood use in its ecological context

6.4.2.1 Temporal trends in fuel wood selection

Taking into account the potential distribution of the main woodland vegetation zones in the Konya plain and its environs, as surmised by the available palaeoecological proxies and modern vegetation analogues, alongside the anthracological evidence, a clear temporal trend can be detected in the use of the different landscape units: the earlier phases (represented by Boncuklu, Can Hasan III and Çatalhöyük East South G (early)) are characterised by a distinctive focus on the management of woodland resources (dominated by riparian and wetland taxa) located in close proximity to habitation sites; by contrast, later phases (South G (late)–H through to the end of South T; West mound) are characterised by the exploitation of more distant vegetation catchment zones (dominated by dryland taxa). However, this general trajectory is not exclusive of the continued use of riparian resources proximate to habitation sites. On the contrary, the regular use of riparian habitats is well attested in the anthracological record, with the ubiquitous presence and routine use of taxa such as Ulmaceae and Salicaceae throughout the Çatalhöyük sequence, in tandem with the ubiquity of taxa that were not as abundant such as *Amygdalus*, Maloideae, *Prunus* and *Pistacia*.

The earlier phases (Çatalhöyük South G (early), Boncuklu, Can Hasan III) dating to the first two millennia of the Holocene are registered in the off-site pollen records (Eski Acıgöl and Akgöl) as periods of low arboreal density (see also Chapter 2, Figures 2.9-2.11) although insect-pollinated taxa (Rosaceae, Maloideae) and poor/sporadic pollen producers (*Pistacia*, *Juniperus*, *Celtis*) are under-represented or absent from the pollen spectra. The presence of *Juniperus* and the Rosaceae in the regional vegetation already from the end of the GS-2 is well attested by the anthracological evidence from Epipalaeolithic Pınarbaşı, providing the earliest palaeovegetation record currently available from south-central Anatolia. Interestingly, the onset of the increasing values for *Quercus* pollen (dated at ~9000 cal. BP in the Eski Acıgöl core; see Fig. 2.10) is more or less synchronous with the sharp increase in the use of this taxon as fuel in South G (late)–H. Arboreal pollen maxima (largely comprising *Quercus* pollen) are not reached in central Anatolia until ~6000 cal. BP (see also Fig. 2.10). Despite continuously increasing regional *Quercus* pollen values, after South P *Quercus* is substituted by *Juniperus* as the dominant wood fuel wood taxon. After South Q-R-S, *Juniperus* values decline. During TP a more local pattern of woodland use is apparent, with Ulmaceae dominating charcoal sample composition, much akin if not identical to that observed in South G (early). This pattern is once more reversed during the West mound occupation, which points to the return of a mixed strategy of exploiting distant (*Juniperus*) and local (Ulmaceae, Salicaceae) woodland resources. The abrupt shifts in the representation of *Juniperus* through the later part of the Çatalhöyük sampled sequence (between South T to TP and the West mound) are likely to reflect a genuine shift in preferences rather than a scenario of deforestation and recovery of this taxon that would have resulted in a more gradual pattern of changing frequencies for this taxon.

6.4.2.2 A theoretical model of woodland vegetation dynamics

Drawing on the discussion of the limitations of existing theoretical models of fuel wood selection (section 6.2) an alternative model is proposed here, tailored to the environmental context of early to mid-Holocene south-central Anatolia (see above, section 6.4.1, and Chapter 2). The proposed model aims to define potential feedback cycles between fuel collection practices and woodland vegetation dynamics. The specific ecological processes highlighted here focus on competitive dynamics in relation to moisture availability and shade tolerance, and the responses of woodland vegetation to a range of management practices including selective and non-selective cutting and thinning, and the removal of deadwood. As the range of time periods covered by the present study also captures (albeit briefly) periods of initial woodland establishment (e.g., the pioneer stages of arboreal colonisation following GS-2 at Epipalaeolithic Pınarbaşı) the proposed model includes additional scenarios relevant to stages of initial woodland expansion.

The first assumption of the proposed model is that high-density woodlands will be dominant under conditions favourable for woodland growth; conversely, low-density stands will be dominant under unfavourable conditions. The second assumption is that selective and non-selective fuel wood collection could be practised in favourable and unfavourable vegetation catchments, regardless of their availability and proximity to habitation sites, by taking also into account that collection strategies are determined by a range of known and unknown environmental, socio-economic, cultural and technological factors (cf. Asouti and Austin 2005, Dufraisse 2006; see also Chapter 4).

It is hypothesised that the selective cutting of taxa from stands growing under favourable conditions (e.g., high-density riparian woodlands growing on alluvial soils; for examples from central Anatolia see Asouti and Kabukcu 2014) may exert negligible effects on stand density, due to the overall high rates of vegetative regeneration and seedling establishment (Salicaceae are a typical example of this). Depending on the nature of woodland management, selective thinning (e.g., coppicing) in patches and/or cycles may drastically improve growth rate by reducing competition. In the absence of thinning, the development of a dense understorey will eventually favour the establishment of shade-tolerant taxa (e.g., *Ulmus*, *Fraxinus*) as dominant. Conversely, selective thinning and/or the removal of dominant shade-tolerant taxa may lead to the establishment of shade-intolerant taxa (e.g., Salicaceae) as dominant. Under this scenario, if thinning is practiced on a regular basis, diversity is unlikely to be affected due to the creation of gaps in woodland stands that will create favourable micro-ecologies for shade-intolerant taxa. By contrast, browsing impacts are likely to retard the growth of young individuals, while regular deadwood removal may also negatively impact seedling germination and survival rates (cf. Marzano et al. 2013: 121). Woodland stands growing under favourable conditions will respond differently under a non-selective fuel wood collection regime. Since cutting and thinning are hypothesised to be non-discriminatory, density and diversity are likely to be largely controlled by ecological competitive pressures. Thus, regular non-selective thinning may promote the establishment of fast-growing taxa as dominants, which will then impact diversity in a negative way when compared to selective practices.

Under unfavourable conditions (e.g., low-density woodlands growing on the alluvial-steppe ecotone and on the low-mid elevation foothill zone receiving ~300-500 mm of annual rainfall) woodland canopy will be characterised by an open structure, regardless of anthropogenic and/or herbivore browsing impacts (for ecological descriptions of modern and historical analogues in central Anatolia, see Asouti and Kabukcu 2014). The pioneer phase of initial woodland establishment is characterised by very low-density canopy, comprising mostly light-demanding shrubs, and a ground cover rich in grasses and forbs. Under a selective fuel wood collection regime, thinning may lead to the gradual establishment of larger individuals among protected taxa, due to the reduction of competition for finite ground moisture resources. This directional process will be accelerated by the impacts of herbivore grazing that will remove competition from grasses, and promote instead the spread of traganthic shrubs and/or topiary/spiny forms of unpalatable taxa (Asouti and Kabukcu 2014). In addition, regular coppicing of intensively managed taxa will enhance rates of vegetative propagation. Through time this may lead to an overall reduction of woodland diversity. Under a non-selective use fuel wood collection regime, diversity would probably remain mostly unaffected, although the growth and spread of fast growing and/or spiny (and for that reason difficult to harvest) shrubs will be promoted.

The following sections provide a detailed description of the reconstructed interplay of environmental conditions, management strategies and vegetation change in the Konya plain during the early to mid-Holocene. This is effected by taking into account the combined results of dendroecological observations, the patterning detected in wood charcoal taxon counts and their relative proportions, and their co-variation with dung-seed and faunal datasets available from Çatalhöyük, in conjunction with the predictions of the woodland vegetation dynamics model described in this section.

6.4.2.3 Characterisation of woodland growth conditions in the Konya plain

The evidence obtained from Epipalaeolithic Pınarbaşı suggests that pioneer woodland communities dominated by *Juniperus* and *Amygdalus* were already established at the foothills of Karadağ before and during the transition to the GI-1, under unfavourable environmental conditions. *Juniperus* is a shade-intolerant taxon that can grow on low-nutrient substrata. For this reason it can rapidly colonise new areas, particularly during the early phases of climate amelioration. The frequency of *Juniperus* increases from the base of the sampled sequence alongside that of *Amygdalus*. This observation provides additional support for an interpretation suggesting that both taxa were early colonisers of the foothill zone surrounding the Konya plain during the transition from GS-2 (21.2-14.7 ka cal. BP) to the GI-1 (14.7-12.9 ka cal. BP) possibly forming very open, low-density woodland stands. *Juniperus* is represented at Pınarbaşı predominantly in the form of twigs and small branch wood that bore ubiquitous signs of compression, traumatic canals and tracheids with deformed and/or collapsed walls. These dendroecological features suggest juniper growth primarily as small and stunted shrubs.

The frequent occurrence of narrow and discontinuous growth rings and traumatic canals in *Juniperus* (see Figures 5.1-5.5) throughout the sampled Konya plain anthracological sequence suggests that, on the whole, *Juniperus* stands grew under considerable environmental stress well into the Holocene. As already mentioned, due to the inapplicability of diameter measurements to this taxon, growth ring width was not systematically measured for *Juniperus* specimens. However, *Juniperus* ring width has been observed to be consistently narrow across all sampled early to mid-Holocene phases. Average growth ring width data available from dendrochronological samples at Çatalhöyük previously analysed by Newton (1996) and the limited measurements undertaken by Asouti (2013) have indicated very low average ring width values throughout the sampled phases (ranging between 0.25-0.77mm). Newton also notes that the Çatalhöyük juniper specimens she examined, derived exclusively from carbonised timbers with ages ranging between 160-500 years, and were generally slow growing (21cm maximum recorded diameter). Newton observed that this growth rate is significantly slower than the rates observed in dendrochronological specimens obtained from Chalcolithic, Bronze Age and Iron Age sites in Anatolia, while it is also slower when compared to modern juniper populations from southern Anatolia (Newton 1996: 24-25).

In the ecological literature it is reported that the main driver of continuously narrow growth rings (indicating slow growth rates) in *Juniperus* are dry and hot climate conditions during the spring and early summer (Lipschitz et al. 1979, Saas-Klaassen et al. 2008, Liang et al. 2011, Esper et al. 2014). This is due to the fact that the majority of the radial growth in junipers consists of early wood tracheids, which are formed predominantly in spring and early summer. Thus, consistently dry and hot growth seasons will result in very slow growth rates, in addition to a higher frequency of false rings, quite *independently* of average annual precipitation levels. Compared to junipers, the dendroecological features of the examined *Quercus* specimens do not indicate equally slow growth rates. This situation likely reflects the ability of deciduous oaks to regulate fluctuations in annual water balance more effectively. Various case studies indicate that the deeper root system of oaks enables them to use more effectively winter precipitation of the previous year, hence allowing relatively uninterrupted early wood formation (Villar-Salvador et al. 1997, Manetti 2002, Cherubini et al. 2003, Corcuera et al. 2004). Junipers on the other hand do not respond in a similar way to increased winter rainfall. Together these anthracological observations on the dendroecological properties of *Juniperus* and *Quercus* charcoals provide direct evidence of the pronounced seasonality of early Holocene climate in central Anatolia, which was characterised by distinctly dry and hot late spring/summer seasons and winter-focused precipitation. This interpretation is in overall agreement with regional palaeoclimatic records (cf. Djamali et al. 2010, Orland et al. 2012).

The majority of growth ring data obtained for angiosperms at Çatalhöyük indicate fluctuations in growth rates that are more likely to be related to management pressures rather than environmental (climate) drivers, although the impact of the latter cannot be excluded altogether (see Figures 5.19 and 5.22-5.23). Growth ring width data collected for both *Quercus* and *Ulmus* indicate the presence of growth release periods (i.e. abrupt increase in growth ring width), beginning in the early phases of the Çatalhöyük sequence for which data are available (South K and L). These values reflect the presence of periods of distinctly improved growth conditions, possibly occurring in a cyclical manner. Furthermore, the distribution of slow growth increments followed by years of significantly improved conditions has also been observed within single oak, elm and hackberry charcoal specimens (see Figures 5.21, 5.22 and 5.23, also Figure 5.63). This suggests a general tendency in these taxa to experience several years of limited growth (or slower growth rates) followed by years of accelerated growth rate, likely arising from brief periods of reduced competition. As discussed in Chapter 4 (section 4.3), this pattern is compatible with observations of growth ring patterns in coppiced woodlands (see also Fig. 4.13). Alternatively, they could indicate the response of individual trees to episodes of thinning of the understorey vegetation in denser woodland stands. Selective thinning of the understorey and the protection of individual trees might also have allowed the development of larger diameter trunks that could have been managed for use as timber. As both *Ulmus* (shade-tolerant) and *Quercus* (shade-intolerant) specimens display the same pattern, it is likely that its underlying causes relate to anthropogenic impacts rather than episodes of natural disturbance.

Growth ring width measurements available for *Celtis* indicate that this taxon might have been impacted in similar ways, although a larger dataset is necessary for confirming this pattern. Ecologically, *Celtis* could have grown in both semi-arid woodlands (including Rosaceae-dominated and *Quercus*/*Juniperus*-dominated stands) as well as riparian and/or wetland edge habitats (see Chapter 2; also Çetik 1985: 254, Asouti and Kabukcu 2014). At Çatalhöyük this is a distinct possibility, considering also the overall wider growth ring width ranges observed for *Celtis* when compared to oaks; The *Celtis* range is also more similar to the ranges observed for *Ulmus* and *Fraxinus*. Overall the pattern of ring width measurements observed for *Quercus*, *Ulmus* and possibly *Celtis* too, is more suggestive of woodland management impacts resulting in alternating periods of reduced and enhanced woodland productivity, rather than environmental (e.g., seasonal moisture deficiency) impacts. Observations of scar/callus tissue and radial overgrowth on specimens from the same taxa (see Figures 5.11-5.14 and Figures 5.21-5.23) provide additional confirmation for the existence of impacts on wood anatomy resulting from intentional cutting, pruning and/or debarking. Additional impacts associated with severe defoliation (i.e. successive very narrow and discontinuous (false) growth rings) (see Figures 5.15, 5.19-5.20, 5.22-5.23) suggest that both dryland and riparian woodlands were potentially affected by herbivore browsing, although not on a routine basis (their presence was not common in the studied assemblage).

An interesting observation arising from the comparison of *Amygdalus* charred specimens between Çatalhöyük and Boncuklu on the one hand, and Pınarbaşı on the other, relates to the differences observed in *Amygdalus* wood anatomy (see also Figures 5.26-5.28). The Pınarbaşı specimens generally display wider rays ((5)8-10 cells wide in the Tangential Longitudinal Section) and more densely packed pores in the Transverse Section. *Amygdalus* charcoals from the other two sites comprise mostly specimens with narrower ray width ((1)3-5(6) cells) and comparatively less densely packed pores. Considering that almost all specimens in question have derived from small diameter wood (twig/branch) it is not possible to ascertain whether these anatomical differences reflect the presence of two different species (and/or species groups) of wild *Amygdalus* or, instead, the effects of different micro-ecologies and growth conditions on almond wood anatomy. Studies of wood anatomical variation in wild and feral tree/shrub populations (cf. Terral 2002, Terral and Durand 2006, Terral and Arnold-Simard 1996, Terral and Mengüal 1999) have indicated that variations in ray width, pore density, and growth ring width could be signalling the effects of different climatic conditions or the impacts of management practices. For instance, lower vessel density has been reported for wild olives growing in conditions of higher moisture availability (Terral and Arnold-Simard 1996). Irrigated olive trees display significantly wider growth rings when compared to trees growing in the wild. It should be noted here that the growth rings of the Çatalhöyük *Amygdalus* specimens (those studied for this thesis derived from the mid-late levels) are seemingly wider compared to the Boncuklu almonds (see Figures 5.27-5.28). This might be an indication that the Çatalhöyük almonds were growing in locations of higher ground moisture availability. Interestingly, both *Amygdalus* and *Pistacia* wood charcoals become increasingly ubiquitous (if not always abundant) towards the later phases of the Çatalhöyük anthracological sequence (see also Fig. 5.41). This might indicate the increasing presence of these taxa on the Çarşamba alluvial fan, possibly as a result of increasing alluvium deposition that raised the level of the fan through time, thus facilitating the colonisation of better-drained alluvial soils and riparian woodland habitats by these taxa. All these observations of local variations in almond wood anatomy and their potential ecological significance need to be verified by future systematic work on a much larger dataset of *Amygdalus* charcoal fragments from all sites. In addition, studies of modern wild, cultivated and managed almond wood anatomy could provide further insights into the nature of the variability observed in the anthracological assemblages.

6.4.2.4 Characterisation of fuel wood collection practices in the Konya plain

As noted already, the continued use of *Amygdalus* at Pınarbaşı from the Epipalaeolithic and well into the Holocene (ranging from the 9th millennium through to the late Neolithic and Chalcolithic periods) suggests that this taxon was preferentially selected for fuel wood for cultural/functional reasons (e.g., its burning properties). A complementary explanation is that *Amygdalus* stands were selectively pruned and/or thinned as a form of landscape management activity (see also Asouti 2003a). It is possible that the long-term predominance of *Amygdalus* reflects a continued practice of selective cutting for this taxon, with the aim of managing and enhancing the structure of the almond-dominated semi-arid woodland located in direct proximity to the site.

The evidence from Can Hasan III also suggests the existence of relatively selective fuel wood collection practices, with a distinctive preference for the collection of Ulmaceae; on the basis of the available evidence it is not clear whether deadwood collection was prominent. Fuel wood collection at Boncuklu was similarly concentrated on riparian and wetland edge habitats. The frequent and abundant use of Salicaceae deadwood also suggests the existence of wet woodland habitats in close proximity to the site that were characterised by high levels of deadwood productivity. Deadwood collection was supplemented by the regular cutting of Salicaceae stands, which likely contributed to the maintenance of the wetland vegetation structure. The evidence available from the non-wood archaeobotanical record (seeds, phytoliths) suggests that various classic wetland taxa such as *Phragmites, Bolboschoenus* and other herbaceous taxa were intensively used throughout the occupation of the site (A. Fairbairn unpublished data, E. Jenkins unpublished data). The abundant presence of *Phragmites* and Salicaceae (rather than *Fraxinus* or Ulmaceae) in this wetland ecosystem might indicate that parts of the woodland catchment were flooded, at least on a seasonal basis. Thus the comparatively higher tolerance of Salicaceae to periodic waterlogging could have been an important element determining their continuous dominance of the wood charcoal assemblage. The ubiquity of the shade-intolerant Salicaceae and their remarkably stable relative proportions in the Boncuklu anthracological assemblage suggest that woodcutting was non-selective and that it resulted in no significant shifts in woodland availability, structure and composition.

The riparian woodland habitats managed by the inhabitants of Çatalhöyük during South G (early) were overall denser and more diverse by comparison to Boncuklu, and likely grew on better-drained soils. They included a mixture of fast- and slow-growing taxa (e.g., *Ulmus*, Salicaceae and possibly *Celtis* too; see also discussion of *Celtis* ecology in modern riparian habitats in central Anatolia by Asouti and Kabukcu 2014). The diversity of taxa exploited from this habitat (including rare taxa such as *Alnus*, *Platanus*, and *Tamarix*) and the continuous presence of shade-tolerant (*Ulmus*, *Fraxinus*) and shade-intolerant taxa (Salicaceae, *Celtis*) suggest that fuel wood collection was non-selective. On the other hand, some *Ulmus* trees might have been protected, as the limited dataset from timbers at the site point to the use of elm especially in the mid-late phases of the site (Asouti 2013). By contrast, the use of *Quercus* and *Juniperus* dryland woodlands, located at some distance from the settlement, was likely far more selective. The abrupt increase in *Quercus* charcoal frequencies in the final phases of the aceramic Neolithic (South G (late)–H) and the equally sharp increase in *Juniperus* frequencies in South Q are likely to represent major shifts in cultural preferences for fuel wood and concurrent temporal shifts in the range of the preferred fuel wood collection catchments.

Overall, the assessment of the anthracological assemblages from the Konya plain sites indicates that riparian woodland catchments were most likely managed for fuel wood in a non-selective manner. Conversely, the use of dryland woodland catchments located at some distance from the sites was likely selective. Therefore the variations observed in the ubiquity and relative frequencies of dryland taxa most likely do not reflect true changes in the availability, composition and spatial extent of dryland woodland vegetation catchments.

6.4.2.5 Characterisation of long-term vegetation management strategies in the Konya plain

The combined analysis of wood charcoal taxon counts and dung-derived non-crop seed counts from the Çatalhöyük long sequence of dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), and their comparison with the available faunal and stable isotope archives, have provided important insights with regard to the long-term development of vegetation management strategies in the Konya plain during the late aceramic and ceramic Neolithic periods.

The dung-seed dataset, as reported by Bogaard et al. (2013) and Filipović (2014), displays a remarkable continuity through time, with some minor differentiation in the late Neolithic with the inclusion of saline wetland taxa (e.g., *Aeluropus*, *Crypsis*, *Sporobolus*). In general, taxa consumed by caprines reflect a broad range of habitats that could have existed in close proximity to the site (marshy and/or saline wetlands, riparian, arable fields and ruderal habitats). Fewer taxa could have been found in drier grounds outside of arable habitats (e.g., *Artemisia*, some Chenopodiaceae, some small-seeded Leguminosae). These could have been components of both the marl plain steppe and, possibly, of semi-arid woodlands as well. Thus, the majority of caprine herding activities were focused in locations proximate to the site, in the marl steppe plain, and in semi-arid open woodlands.

Such a pattern of herd movement has been suggested by the oxygen and strontium isotope evidence obtained from caprine teeth at Çatalhöyük (Henton 2010, 2013, Bogaard et al. 2014b). Henton has proposed that upland herding was not commonly practiced at Çatalhöyük: 89% of sheep teeth at the site indicate relatively warm and dry summer grazing locations on the marl steppe, the alluvial fan, the sand ridges and possibly the limestone terraces too. Only 11% of the specimens have been interpreted as indicating herding at higher altitudes, further away from the marl plain, possibly under cooler summer conditions and/or in sheltered valleys. A smaller number of sheep teeth (7) were also sampled for strontium isotope analysis, further narrowing the spatial range of potential lowland pastures to locations on the plain. 1 specimen of the 7 fell within the range of strontium values characteristic of the limestone terraces (Bogaard et al. 2014b). These data clearly agree with the evidence provided by the dung-seed data suggesting the herding of caprines on the plain. Caprine carbon and nitrogen isotope ratios provide a more detailed view of the diet of individual animals through their lifespan. As argued by Pearson (2007, 2013) carbon isotope ratios from South G (early) reflect a more restricted dietary range amongst individuals, suggesting that sheep were more limited in the range of environments they encountered during their lifetimes. A similar pattern is revealed by the combined analysis of wood charcoal taxon counts and dung-seed counts from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999), which indicates that charcoal samples with a more prominent presence of Ulmaceae and Salicaceae are coterminous with dung-seed composition dominated by taxa of wetland origin (see Figures 5.79, 5.80). This evidence, alongside the available stable isotope data, suggests that that in South G (early) fuel collection and herding activities were concentrated on riparian environments located in the immediate environs of the site.

During the later phases of occupation at Çatalhöyük, caprine carbon and nitrogen isotope ratios become more variable amongst sampled populations, signalling to the possibility that either herds were divided and ranged in different locations, or that collectively they encountered more diverse environments through their lifetimes (Pearson 2013). The shift in the variability of carbon isotope ratios at Çatalhöyük occurred concurrently with the abrupt increase in the use of *Quercus* as fuel wood in

South G (late)–H, thus suggesting that the spatial expansion of some herd management activities was closely tied to activities relating to woodland management. In addition, phases South H-P also display a higher abundance of hunted fauna including cervids that are characteristic of woodland environments, and equids that inhabited steppe ecotones on the plain further away from the site (Russell and Martin 2005, Russell et al. 2013). Interestingly, the increasing abundance of *Juniperus* fuel wood at Çatalhöyük (beginning in South Q) appears to be closely correlated with increasing caprine herd size (Russell et al. 2013). The caprine carbon isotope evidence from the same phases through to the end of the South Area sequence also suggests an increasingly expansive herding range, with more variable carbon isotope ratios of the sampled caprines (Pearson 2013).

6.4.2.6 Modelling the seasonality of woodcutting activities and fuel wood collection and use

Wood cutting activities are normally carried out during the autumn/winter dormancy period, due to the ease of cutting larger branches or trunks at a time of arrested wood growth. Woodcutting during the dormancy period is also more advantageous with regard to the recovery of the trees from trauma, and can prevent severe trauma in the following year’s growth season. Once wood is cut, a period of seasoning ranging from 6 months to a year is necessary before it can be used as fuel. Unseasoned wood generally burns very slowly and produces less heat and more smoke and soot compared to seasoned wood. In this respect, it is possible that wood cutting activities were concentrated in the autumn/winter periods, whereas collection of cut logs could be continuous throughout the annual cycle. Variations to this pattern might have existed between proximate riparian habitats and more distant dryland catchments, given that riparian woodland patches might have also been cleared for cultivation. In the anthracological assemblage both seasons of cutting (i.e. spring/summer and autumn/winter) have been indicated by twigs of riparian taxa preserving terminal rings (e.g., Ulmaceae, Salicaceae); conversely only autumn/winter cutting has been detected for dryland taxa, as suggested by the small number of *Quercus* twigs for which such observations were feasible. Collection of dry deadwood from the woodland floor could have taken place year-round, although its timing and intensity would also have depended on the deadwood productivity rates of different woodland habitats.

Cutting of branches and limbs for fuel, thinning of saplings or sprouts, and the felling of large trunks are likely to have been carried out in cycles of different duration. Cutting of small diameter fuel wood could have been carried out in the same woodland patch year after year, with some negative impacts on woodland regeneration rates. However, extensive thinning or felling could only have been repeated following a sufficient amount of time in order to allow for the recovery of individual trees. These cycles are reported to range between 4-7 years in traditional woodland management systems of Europe (Peterken 1981: 24). In south-central Anatolia, they could have occurred at longer intervals due to its drier climatic conditions and slower woodland growth rates (although these effects are likely to have been much less pronounced in riparian woodlands).

Due to the fact that dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) from different spaces belonging to the same phase reflect a similar charcoal sample composition, it is conceivable (albeit difficult to prove) that the inhabitants of Çatalhöyük had unrestricted access to a range of different fuel wood catchments. It is possible (although evidence is limited) that cutting of oak and juniper wood was carried out during autumn/winter (possibly a group task) thus enabling the collection of already seasoned logs and/or dry deadwood and their transportation back to the site in tandem with the cutting of new logs. Throughout the year, in accordance with other routine and non-routine subsistence and other economic activities, small amounts of dry wood could have been collected and transported back to the site. The increasing abundance in the use of oak and juniper fuel wood from South G (late) –H might be linked to an increase in the frequency of more long-ranging herding and hunting trips. Travelling at greater distances for other purposes (including non-routine trips for the procurement of raw materials such as stone, obsidian and clay) might also have enabled bringing back to the settlement smaller quantities of dry wood. In turn, such practices, involving cyclical periods of woodcutting and collection of fuel and timber wood at variable distances from the site, could have encouraged increasing management of woodland vegetation through time, in order to ensure sustainable supplies of timber and high-quality fuel wood. Thus, it is proposed that, while wood collection in proximate riparian habitats was largely non-selective, semi-arid woodlands were actively managed through a range of selective strategies aimed at promoting the growth rates of preferred species such as oak and juniper.

In riparian woodlands located in the immediate environs of the site, it is argued that the bulk of fuel wood collection likely took place during the autumn/winter dormancy period, with subsequent collection of dry wood carried out at shorter (e.g., daily) cycles. In the summer months, requirements for better quality wood might have been higher, especially if seasonal activities (e.g., larger-scale food preparation for feasting events or food processing, pottery production, etc.) generally required increased levels of fuel wood consumption. At the same time, there is no evidence to suggest that poor quality fuels were used at any point as a strategy for mitigating real or perceived fuel shortages and/or fuel wood scarcity. Rather, particular combinations/fuel recipes (e.g., mixtures of *Quercus*, dung and grasses) were used for specific tasks that might have required higher fuel loads (e.g., ceramic firing). Such functional allocation of fuel resources would have allowed the sustainable and more efficient use of fuel supplies throughout the annual cycle, as well as catering for function-specific pyro-technological requirements.

6.5 Regional trends in woodland vegetation and use

On the whole, continuity in fuel wood use practices is evident when considering the whole assemblage from south-central Anatolia, providing evidence that communities were closely monitoring local woodland resources (i.e. at Pınarbaşı, Boncuklu, Can Hasan III and Çatalhöyük). Through time the knowledge, skills and practices developed in the management of local woodlands were transferred to more distant woodlands catchments. Integration of woodland management activities with a range of other economic activities relating to everyday needs (e.g., sourcing of raw materials, herding, hunting) enabled the continued use of proximate and more distant catchments for over a millennium at Çatalhöyük without placing a considerable strain on other routine tasks and activities, including agropastoral production that formed the mainstay of the local economy.

Within the regional context, the early appearance of *Juniperus* evidenced at Epipalaeolithic Pınarbaşı resonates with the anthracological assemblages of two other Epipalaeolithic sites in Anatolia, Öküzini and Karain B. Their fuel wood assemblages similarly consist of *Amygdalus*, *Juniperus* and Maloideae (Martinoli 2004). In southwest Syria, at Baaz (spanning the GS-1 and the early Holocene) *Amygdalus* and

Pistacia are also abundant, alongside riparian taxa (Deckers et al. 2009) in a pattern that is broadly similar to the composition of the anthracological assemblages retrieved from the Epipalaeolithic and aceramic Neolithic phases at Pınarbaşı and Boncuklu. The importance of *Juniperus* as a pioneer taxon in the vegetation history of Southwest Asia during the late Pleistocene and early Holocene transition is further attested by its predominance in anthracological assemblages retrieved from sites located in the arid zone of the southern Levant (in the Negev and in Jordan) dated to this period (Baruch and Goring-Morris 1997, Austin 2007).

At other early Holocene sites in eastern and southeast Anatolia and northern Syria (Çayönü, Hallan Çemi, Körtik Tepe, Göbekli Tepe, Cafer höyük, Abu Hureyra, Mureybet, Jerf el-Ahmar) *Quercus* gradually becomes more common alongside *Pistacia*, Salicaceae, *Amygdalus*, Maloideae and *Celtis* (cf. van Zeist and de Roller 1991/2; Willcox 1992, 1999, 2002, Rosenberg et al. 1995, Helmer et al. 1998, Neef 2003, Riehl et al. 2012) (see also Table 2.2). This gradual increase in *Quercus* resonates with the evidence from the Konya plain (see also discussion in Asouti and Kabukcu 2014). A similarly gradual appearance of *Quercus* is seen at sites on the Zagros, with deciduous oak appearing during the 7th millennium cal. BC (Asouti pers. comm.). The existence of these robust regional trends in the appearance and frequencies of fuel wood taxa is significant. It confirms that, at a regional scale, anthracological remains deriving from fuel wood debris reflect temporal consistency in the timing of the appearance and spread of key woodland taxa across the region. They are thus capturing major shifts in woodland vegetation composition with a degree of precision that is currently unmatched by palynological studies, which (for their greater part) are poorly dated and preserved, while also failing to record insect-pollinated taxa and poor/erratic pollen producers. Therefore, it can be argued that, apart from the distinct advantages provided by anthracology as a method for investigating the origin and long-term development of early anthropogenic landscapes in Southwest Asia, it also provides a valuable source of direct evidence for vegetation and palaeoenvironmental reconstruction.

6.6 Summary

This thesis has demonstrated that anthracological remains retrieved and studied through the application of appropriate sampling, sub-sampling and analysis protocols are representative of past woodland composition, ecologies (including woodland growth conditions), prehistoric fuel economies and woodland management strategies. These aspects were investigated in detail for a long anthracological sequence obtained from habitation sites in south-central Anatolia (Turkey) spanning the period between 15-7.5 ka cal. BP. The results of the analysis suggest that pioneer taxa such as Juniperus and Amygdalus (very under-represented or altogether absent in the regional pollen diagrams) were used as fuel by Epipalaeolithic hunter-gatherers in the Konya plain from as early as the end of the GS-2. Furthermore, qualitative observations of growth ring morphology and dendroecological features (especially from Juniperus) confirm the prevalence of a highly seasonal climate in south-central Anatolia during the early Holocene, characterised by hot and arid summer and wet winter seasons, in line with other regional palaeoclimatic proxy records.

During the early to mid-Holocene, the changing proportions of fuel wood taxa in the anthracological assemblages demonstrate a clear temporal: the earlier phases (represented by Boncuklu, Can Hasan III and Çatalhöyük East South G (early)) show a distinctive focus on wetland and riparian environments. In later periods (post-9000 cal. BP) there is compelling evidence for the management of more distant woodland catchment zones translated in the dominant use of semi-arid woodland taxa, alongside riparian ones (the latter available in direct proximity to habitation sites). The temporal patterning in fuel wood use is interpreted as representing selective use of taxa in more distant locations and non-selective use of taxa in closer woodland catchments, with an overarching preference for deadwood collection across all sites. In addition, evidence from primary fuel use contexts (e.g., hearths, firespots) at Çatalhöyük East, obtained through the multivariate analysis of charcoal and dung fuel remains, suggests that specific fuel mixtures (including oak wood, dung and reeds) might have been used in outdoor fires for specific purposes (e.g., ceramics firing).

With regard to the reconstruction of prehistoric woodland vegetation and its changes through time, the sharp increase in Quercus charcoal frequencies at Çatalhöyük East in South G (late)–H is more or less synchronous with the onset of increasing values for Quercus pollen (dated at ~9000 cal. BP) in the Eski Acıgöl core in Cappadocia. However, later fluctuations in the charcoal frequencies of this taxon are at odds with the evidence from pollen spectra for the continuing expansion of oak until 6000 cal. BP. After South P, Quercus is substituted by Juniperus as the dominant fuel wood taxon.

The abrupt shifts in the representation of Juniperus charcoal through the later part of the Çatalhöyük anthracological sequence (from South T to TP and the West mound) are interpreted to reflect genuine shifts in fuel wood preferences, relating to changes in subsistence activities, as indicated by coeval changes in caprine herding (assessed through the multivariate analysis of charcoal, dung and select faunal remains). These results are further supported by stable isotope studies of caprine diets through time (Pearson 2013).

Qualitative and quantitative dendroecological methods (ring width analysis and recording of traumatic growth) applied in the present study demonstrated that selective pressures on semi-arid woodlands (e.g., Quercus), especially during the occupation of Çatalhöyük, culminated in the development of locally distinctive woodland management practices (including coppicing and selective thinning).

Methodologically, the present study re-assessed wood charcoal taphonomy through a detailed examination of charcoal density values and quantitative and qualitative diameter estimation techniques, supplemented by the systematic application of multivariate statistical analyses, all previously untested in such a comprehensive manner by anthracological research in Southwest Asia. Wood charcoal density distributions at all sites confirmed conclusions by Chabal et al. (1999) and Asouti and Austin (2005) that the taphonomic impacts of burning, deposition, burial and post-depositional disturbance of fuel waste, result in a random distribution (left-skewed) of charcoal densities across all context types. The application of diameter measurements and qualitative calibre estimation methods showed that anthracological assemblages of fuel wood debris are characterised by the over-representation of small calibre portions of the logs placed into a fire. Thus, they do not appear to be representative of the full spectrum of original sizes of wood used as fuel. Lastly, the PLE characterisation of fuel wood collection as either selective or non-selective (depending on environmental availability and settlement size) was revised in the context of the present study. It was demonstrated that fuel wood collection can be selective and non-selective independently of the relative abundance and density of woodland habitats in the landscape. An alternative model was proposed (taking into account taxon frequencies as well as the dendroecological attributes and growth conditions of individual fuel wood taxa) which permits reconstructing the full spectrum of people-woodland interactions and woodland management in prehistory.

CHAPTER 7: CONCLUSIONS

This thesis presents the results of the analysis of the anthracological remains from four archaeological sites in the Konya plain of south-central Anatolia, which to date represents one of the longest anthracological sequences reported from Southwest Asia, spanning the time period between ~15-7.5 ka cal. BP. As such, the results of the present study have enabled three important issues to be addressed in the context of woodland use, vegetation change dynamics and anthropogenic impacts in south-central Anatolia: (a) reconstructing woodland vegetation and fuel use and their changes through time during this critical period for the development of settled life and early agricultural economies, (b) examining the nature and scale of woodland management activities and anthropogenic impacts on prehistoric woodland vegetation, and (c) evaluating the representativeness of anthracological assemblages for reconstructing late Pleistocene and early to mid-Holocene woodland ecologies in south-central Anatolia, in relation to climate, woodland growth conditions and human impacts. The topic of vegetation reconstruction in archaeology and paleoecology is often evaluated by way of comparing shifts in the relative abundance and presence/absence of certain key taxa, framed around a set of inferred prehistoric human impacts arising from the use of resources available in the landscape. In the specific context of Southwest Asia, two key aspects are often overlooked: first that, for various taphonomic as well as environmental and ecological reasons, palaeovegetation archives are unlikely to provide a complete representation of the actual presence or absence of taxa; second, that the human use of vegetation resources (in particular woodlands) does not invariably lead to their destruction.

This thesis has sought to bring into the field of palaeoenvironmental reconstruction two types of primary evidence relating to the use and ecology of prehistoric woodlands in south-central Anatolia during the Pleistocene-Holocene transition: (a) charcoals from carbonised wood fuel waste debris retrieved from primary and dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) were identified and analysed, using a range of qualitative and quantitative techniques. They provided direct evidence of the taxa used as fuel wood in the past, and the changes in their relative proportions through time; (b) the dendroecological attributes of wood charcoals were studied in detail, yielding a wealth of information regarding the ecological conditions of tree and shrub growth, and the ecological properties (form, structure, density and dynamics) of the woodland vegetation catchments exploited by the prehistoric communities. The changes observed in fuel wood use and in woodland ecologies across space and time were evaluated within a broader theoretical framework of anthropogenic vegetation dynamics, by evaluating the impacts of selective and non-selective use of woodland resources. It was argued that rather than reflecting directional negative impacts through the time period under consideration, the available evidence points instead to the local development of woodland management strategies and their co-evolution with subsistence economies and settlement patterns through time.

The main conclusions of this study regarding the reconstruction of prehistoric fuel wood use and the vegetation history of south-central Anatolia, and its implications for the theoretical and methodological development of anthracology are outlined below, alongside suggestions for further research in palaeovegetation studies in Southwest Asia.

7.1 Methodological and analytical advances

A number of methodological and analytical techniques were utilised in the present study, some of which (e.g., multivariate analyses) had previously been applied only in a limited number of anthracological studies in Southwest Asia and beyond. Other techniques, such as dendroecological analyses, have not been previously applied to any other site in Southwest Asia. Furthermore, the comprehensive evaluation in the context of an archaeological case study of diameter size-classes and ring width measurements as proposed by other authors (e.g., Marguerie and Hunot 2007, Dufraisse 2008, Paradis et al. 2013) represents a unique contribution of the present study to the discipline of anthracology.

A number of methodological and analytical inferences were made with regard to the application of these techniques. Strict sampling and subsampling protocols set out by previous anthracological research, as outlined in Chapter 4 (see also Chapter 5, section 5.1) were applied in order to maximise the potential representativeness of the anthracological dataset with regard to prehistoric fuel economies. When available, both primary fuel waste and dispersed (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) contexts were examined, thus establishing a link between individual burning events and long-term accumulations of fuel waste debris. It was demonstrated that the multiplicative effects of mass loss during burning, deposition, burial and post-depositional disturbance of fuel waste result in a left-skewed random distribution of charcoal densities across all context types (Chapter 5, section 5.2; Chapter 6, section 6.1). The overall consistency observed in the relative proportions of the charcoal taxa contained in dispersed contexts within each phase confirmed, as also stated by Chabal et al. (1999) and Asouti and Austin (2005), that anthracological assemblages from dispersed contexts (*'charbon de bois dispersés'* cf. Chabal 1992, Chabal et al. 1999) provide an accurate representation of the relative proportions of the taxa used as fuel wood in the long-term (Chapter 5, section 5.3).

The applicability and representativeness of the currently available qualitative and quantitative wood calibre estimation techniques were examined in detail. It was demonstrated that, regardless of context type and degree of post-depositional alteration, the preservation of a high number of charcoal fragments derived from the small calibre portions of wood logs used as fuel is favoured; fragments derived from the larger diameter portions of wood logs rarely survive taphonomic processes, with the complete destruction of sapwood during combustion likely to represent the most influential process in this respect (Chapter 5, sections 5.4 and 5.5). Thus, the utility of wood calibre measurements for reconstructing preferred fuel wood diameter and volume and (by implication) woodland management strategies (e.g., Dufraisse 2008) is questioned. Although only a relatively small number of fragments were analysed through quantitative diameter estimation methods, the application of the qualitative methods of Marguerie and Hunot (2007) on a much larger charcoal specimen population produced the same pattern of curvature degree classes. Thus, the evidence provided by the present study indicates that the taphonomic impacts of burning, and (post)depositional processes on wood fuel calibre have been largely overlooked by the proponents of these approaches. In light of these results, it is argued that during burning, due to constant mixing and re-kindling, the outer diameter portions of wood are largely consumed by fire; among the charcoal fragments that survive this process small diameter heartwood fragments or those fragments closer to the outer parts of the hearth (including distal ends of incompletely burnt logs, branches and twigs) are more likely to be preferentially preserved. This hypothesis concerning the preservation potential of different diameter size-classes will be tested by future experimental research involving different taxa, wood logs of different calibre, and hearth types in order to test and describe more precisely the effects of burning on the preservation of different diameter size-classes.

In addition to diameter calculations, sequential ring width measurements were carried out for charcoal fragments included in the quantitative diameter estimation sample set from Çatalhöyük. Diameter measurements and their corresponding minimum, maximum, average and median growth ring width measurements were used to assess the independence of ring width from the age/calibre of the fragments (Chapter 5, section 5.5) thus eliminating the possible skewing effect introduced to ring width measurements as a result of tree age. Since no correlation was detected between ring width values and estimated diameter sizes for each taxon, per-phase ring width measurements were used as a random sample of the growth ring widths of each taxon in a given woodland catchment for a set period of time. In this way, any sudden releases in radial growth would cluster together, and a significant distance between years of narrower (average) growth and years of radial growth release could be identified. Thus, ring width measurements for each taxon were evaluated per phase, by looking at their distribution patterns. Some limited conclusions were drawn on the possible management of *Quercus* and *Ulmus* by thinning and selective cutting, beginning with South K, as indicated by the presence of growth release periods (i.e. abrupt increases in ring width). These inferences concerning woodland management at Çatalhöyük will be tested formally through a future study of growth ring width patterns in preserved charred timber specimens from this site.

In addition to quantitative techniques, a number of qualitative anatomical features of charcoal specimens relating to the growth conditions and the status (decayed/non-decayed) of wood prior to burning were recorded (Chapter 5, sections 5.1, 5.4). This analysis enabled evaluation of the presence of specific growth anomalies and their covariance with individual taxa. It was demonstrated that *Juniperus* specimens from all phases of occupation generally contained more abundant signs of ecological stress, as indicated by the frequent presence of narrow/false rings, traumatic canals and deformed tracheids. With the exception of some taxa that are naturally resistant to fungal infestation (*Juniperus*) a great majority of the specimens from Çatalhöyük displayed signs of pre-burning decay including fungal hyphae, collapsed vessels and boreholes, suggesting that they were either collected as deadwood and/or stored (on and/or off-site) for a period of time for seasoning prior to burning. It was demonstrated that a detailed analysis of dendroecological features and their exploration through multivariate techniques can provide valuable insights into the co-occurrence of specific features in each specimen and between taxa, thus capturing the full range of dendroecological characteristics preserved in the dataset. In future research, the applicability of these methodologies to other sites and geographical regions within Southwest Asia will be tested. In addition, the application of dendroecological methods will be expanded to incorporate measurements of early wood pore/tracheid size and pore density, in order to address additional questions regarding the modelling of levels of ground moisture availability and growth season aridity.

Lastly, the potential for evaluating wood charcoal taxon counts alongside other datasets were tested, through the application of multivariate techniques (Chapter 5, section 5.6). One of the aims of this approach was to evaluate the nature of wood and dung fuel use at Çatalhöyük in order to obtain a more complete picture of the ‘fuel economy’ as a whole, thus bridging the interpretations proposed by different specialist methodologies (e.g., of wood charcoal vs. dung-seed remains). This analysis provided some interesting results with regard to the combination of taxa used in outdoor fire features and related activity areas. The co-occurrence of dung fuel from caprines grazed locally (wetland edge habitats, cultivated fields) and high-quality oak wood fuel in external fires suggested the existence of particular fuel ‘recipes’, possibly in relation to specific pyro-technological tasks such as ceramic firing. The potential co-variation in wood charcoal, dung-seed and faunal datasets from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) was also investigated through multivariate techniques (Chapter 5, section 5.6). Multivariate analyses demonstrated that the dung-seed dataset correlates more closely with riparian wood charcoal taxa. The sharp increase of *Juniperus* charcoal frequencies in the later phases of the Çatalhöyük East mound (South Q-T) coincides with faunal evidence for increasing caprine herd sizes, while carbon and nitrogen stable isotope values of caprine remains also indicated an increasingly expansive herding range. Based on the assessment of these datasets it was proposed that shifts in the wood fuel economy were not driven by changes in woodland availability or fuel wood scarcity. Instead they appear to correlate in space and time with coeval shifts in other landscape-scale activities such as animal management and herding. The multivariate exploratory techniques and their applications in the present study will be used more extensively in future research involving the systematic integration of anthracological, archaeobotanical and zooarchaeological datasets, from these and other sites in Southwest Asia and beyond. Particularly in the case of prehistoric Southwest Asia such an integrated approach provides a distinct opportunity to overcome traditional disciplinary priorities and boundaries, and achieve novel, powerful insights into the development and co-evolution of prehistoric landscape practices and anthropogenic impacts on past vegetation in the transition from foraging to farming and the establishment of early agricultural economies and agroecologies.

7.2 Palaeoecology, prehistoric woodland use and anthropogenic impacts

With regard to palaeovegetation studies and wood fuel use, the present study built on a wealth of completed and ongoing anthracological research focusing on south-central Anatolia. The results of this study, with the incorporation of previously published anthracological results from the sites of Çatalhöyük East and Pınarbaşı in the Konya plain, provide a very rich archive (largely unmatched elsewhere in Southwest Asia) spanning the late Pleistocene and the early to mid-Holocene. The anthracological results from Epipalaeolithic Pınarbaşı have provided new insights into the pioneer stages of woodland establishment following the onset of the warm-wet climatic episode GI-1, including the spread of *Juniperus*, *Amygdalus* and *Pistacia* into the region from a very early stage, which was previously undetected in the regional pollen records. With the onset of the early Holocene, the key semi-arid woodland taxa of the region were already established in the landscape: *Quercus, Juniperus, Amygdalus, Pistacia*, Maloideae and *Prunus*. Furthermore, the mosaic of early Holocene landscapes in the Konya plain included a diverse range of riparian and wetland edge woodland habitats comprising taxa such as Salicaceae, Ulmaceae, *Tamarix*, *Fraxinus* and possibly *Celtis* as well. These woodland habitats were particularly productive and provided a steady supply of fuel wood to the inhabitants of Boncuklu, Can Hasan III and Çatalhöyük for a considerable period of time. During the early stages of settled life and the establishment of the first agropastoral economies in this region, the availability of riparian woodlands in close proximity to habitation sites likely formed an important consideration for settlement location. It also enabled the local development of woodland management strategies specific to the environmental and climate conditions of south-central Anatolia.

The evidence from the present study indicates that through time, spatial proximity of fuel wood resources, and their relative abundance and density in the landscape were not the primary determinants of fuel wood use. Neither was the spectrum of fuel wood taxa limited to high-quality fuels. Instead at Boncuklu, Can Hasan III and Çatalhöyük, a mixture of local and more distant fuel wood sources were used, albeit in differing proportions. The strongest patterning observed in the anthracological dataset is explained by site-specific temporal shifts in preferred fuel taxa, with an overall trend for increasingly expansive use of woodland catchment zones through time culminating in the mixed fuel economy of the Çatalhöyük East and West mound occupations. Meanwhile, 'local' riparian woodlands were continuously used both as a source of fuel wood and (to a lesser extent) timber. Thus, a multitude of distinct ecological zones were continuously used by communities in the Konya plain throughout the early to mid-Holocene. There is some indication that more mobile, non-farming communities (e.g., at Pınarbaşı) practised more expedient, opportunistic fuel wood collection strategies. A strong preference for deadwood is evident from the earliest phases of occupation during the Epipalaeolithic at Pınarbaşı. By contrast, the settled forager-cultivator (Boncuklu) and farmer (Can Hasan III, Çatalhöyük) communities, practised selective and non-selective fuel collection and use strategies that were largely independent of woodland availability per se.

The results of detailed dendroecological analyses have suggested that summer aridity was more pronounced in south-central Anatolia during the early to mid-Holocene, while precipitation was focused in the winter season. Evaluation of the distribution of growth ring width measurements has indicated the presence of woodland management impacts on the productivity of *Quercus* and *Ulmus* beginning with South K and L at Çatalhöyük. A mixture of selective cutting and thinning, possibly on a rotation-cycle that might have been aimed at the production of fuel wood and larger poles, improved radial growth rates and increased the productivity of these taxa. Limited scale browsing impacts on *Quercus*, *Ulmus* and *Fraxinus* have also been detected.

The available literature (Chapter 4) suggests that the economic and environmental filters on fuel wood collection are numerous. Furthermore, fuel wood collection, even when it is expedient in nature, can be selective or non-selective in a multitude of ways, which can include the selective protection of some taxa, the avoidance of others, or the preferential collection of deadwood, or combinations thereof. The variables involved can be cultural, socio-economic, or environmental. However, the complexity of these parameters does not preclude charred fuel waste debris retrieved from dispersed contexts (‘*charbon de bois dispersés’* cf. Chabal 1992, Chabal et al. 1999) that were accumulated in the long-term from being representative of the relative proportions of the wood taxa used as fuel in the past. Neither does it preclude the studied specimens from being representative of the ecological conditions of past woodlands harvested for fuel and timber. Herein lies the most profound advantage of anthracology, in that it studies the charred remains of wood that was intentionally collected and burnt as fuel, which also carry a range of anatomical features that can be used to reconstruct the composition, structure, form and function of past woodlands. Thus, it is proposed that (whenever possible, depending on the quality of charcoal preservation) the combined analysis of wood charcoal taxon proportions and of the dendroecological attributes of individual specimens should be undertaken on a routine basis. Furthermore, dendroecological methods and exploratory multivariate techniques provide important evidence with which to explore and reconstruct past people-environment interactions. Such an approach could provide the empirical basis for investigating the origin and regional histories of managed landscapes. It can also shed light on the nature of knowledge acquisition and transmission relating to prehistoric woodland management practices, and their integration with other landscape-scale practices such as herding and farming.

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Prehistoric vegetation change and woodland management in central Anatolia: late Pleistocene-mid Holocene anthracological remains from the Konya Plain

(Volume 2: Tables, Figures and Appendix)

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Philosophy by Ceren Kabukcu

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Dates cal BP	Greenland Event stratigraphy terminology	Climatic episode	General climate trends in Southwest Asia
21,200-14,700	Last Glacial	GS-2	Cold, arid (low precipitation/evaporation)
14,700-12,650	Bølling-Allerød interstadial	GI-1	Warm and wet (increasing temperatures [14.5-18.0^{o}C] and precipitation [~550-750 mm p.a.]
12,650-11,500	Younger Dryas stadial	GS-1	Cold, arid (low precipitation and temperature)
11,500-8200	Early Holocene		Warm and wet (increasing temperatures ~14.5-19.0^{o}C and precipitation ~675-950 mm p.a.); increased seasonality of climate with wet winters and dry summers from ~10.5 ka BP
8200-present	Mid Holocene to present		Establishment of modern climatic regime (temperatures ~18.0-22.0^{o}C; precipitation ~450-580 mm p.a.); aridification impacts compounded by anthropogenic impacts on the environment

Table 2.1: Major climatic regimes in the Eastern Mediterranean from the Last Glacial Maximum to the Holocene (based on Bar-Matthews et al., 1997, 1999, Robinson et al. 2006, Orland et al. 2012, Walker et al. 2012).

	Hallan Çemi[1]	Qermez Dere[2]	Körtik Tepe[3]	M'lefaat[4]	Göbekli Tepe[5]	Çayönü[6]	Cafer höyük[7]	Aşıklı höyük[8]	Can Hasan III[9]	Ganj Dareh[10]	Tepe Abdul Hosein[11]	Jarmo[12]	Aşvan[13]
Quercus	▨		▨ D?	▨	▨	▨ D?	▨	▨	▨			▨ D	▨ D
Pistacia	▨	▨	▨	▨	▨ D	▨	▨	▨ P	▨	▨ D	▨ D	▨	▨
Amygdalus	▨		▨		▨	▨	▨	▨	▨ D	▨	▨		▨
Maloideae			▨		▨				▨			▨	
Riparian taxa	▨ D	▨	▨ D	▨ D	▨	▨	▨ D	▨	▨ D	▨	▨	▨	▨
N=(number of frags/number of samples)	**125/3 flotation**	**~6g/4 flotation**	**1487/6 flotation**	**161/4 flotation**	**308/ hand-picked & flotation**	**?/23 hand-picked & flotation**	**?/84 hand-picked & flotation**	**? flotation**	**?/97 hand-picked**	**?/76 hand-picked & flotation**	**?/20 hand-picked & flotation**	-	**?/26 hand-picked**

Table 2.2: Summary table of the wood charcoal macro-remain evidence derived from other prehistoric (Epipalaeolithic-Chalcolithic) sites in the Irano-Anatolian region of Southwest Asia (due to the variable standards of retrieval and reporting only ubiquity/taxon presence data – shaded boxes – are presented here; D denotes the "dominant" taxon in each assemblage, as far as this could be established by the available information and the published descriptions of the anthracological assemblages (in the cases of Qermez Dere, Ganj Dareh and Tepe Abdul Hosein the reported material has been very limited). Data sources: [1]Rosenberg et al. 1995, 1998, [2]Watkins et al. 1989, [3]Riehl et al. 2012, [4]Savard et al. 2003, [5]Neef 2003, [6]van Zeist 1972, van Zeist and de Roller 1991/2, [7]Willcox 1991, [8]Woldring and Cappers 2001, Woldring and Bottema 2001/2, [9]Willcox 1977, 1978, 1979, 1991, 1992, Kabukcu (present study); [10]van Zeist et al. 1984, [11]Willcox 1990, [12]Asouti (unpublished data; ongoing study), [13]Willcox 1974 (modified after Asouti and Kabukcu 2014).

	Nahal Neqarot[1]	WF16[2]	Ma'aleh Ramon[1]	Abu Salem[1]	Saflulim[1]	Ramat Harif[1]	el-Hemmeh (PPNA)[7]	Dhra‘[3]	Tell Qarassa N[4]	Tell es-Sultan[5]	‘Ain Ghazal[6]	Basta[6]	el-Hemmeh (LPPNB)[7]
Pinus					0.72								
Juniperus	82.72	57.58	40									65.5	
Pistacia		3.16	58	99.95	61.59	99.62	70.71	+	59.48		<3	72.7	6.30
Quercus deciduous											>43		
Quercus evergreen		2.17					2.99	+	+		<3	3.7	0.65
Rhamnus	9.69	0.12	0.2	0.03		0.03	0.63						
Amygdalus/Prunus			0.2	0.02			2.84		37.25	+		10.9	1.94
Maloideae							0.16			+	+		0.48
Olea										+			
Punica?										+			
Ceratonia										+			
Capparis		1.38								+			0.48
Leguminosae		0.67						+		+			
Ephedra	6.28	0.12	1.2			0.35		+					
Chenopodiaceae	0.79	3.99	0.4				7.24	+		+			6.30
cf. Asteraceae													1.13
cf. Labiatae													1.94
Ziziphus/Paliurus					37.66		1.73			+			1.29
Zygophyllum		0.26											0.48
Salicaceae		15.51					7.56	+	0.65	+	+	+	20.52
Tamarix	0.26	7.14					0.63	+		+	+	+	14.70
Fraxinus							1.57	+		+	+	+	34.73
Platanus										+			
Ficus		6.31					3.94	+		+			9.05
Total charcoal fragment count	**382**	**2534**	**500**	**6620**	**138**	**6766**	**635**	**26**	**153**	**47**	**~1300**	**~1535**	**619**

Table 2.3: Published anthracological assemblages from late Pleistocene and early Holocene sites in the southern Levant (Taxa frequencies are expressed as % fragment counts, except for ‘Ain Ghazal and Basta (explained below). + denotes presence in hand-picked charcoal assemblages (indicated below) or uncertainty in the precise quantitative value of the frequency/presence values. Data sources: [1]Baruch and Goring-Morris 1997, [2]Austin 2007, [3]Asouti, previously unpublished charcoal identifications produced for ^{14}C dating of handpicked specimens; [4]Arranz 2011 & pers. comm.; [5]Western 1969, 1971 hand-picked charcoals; [6]Neef 2004a-b; [7]Asouti pers. comm. – ‘Ain Ghazal: ubiquity scores (% presence) were calculated by combining hand-picked and flotation samples; Basta: ubiquity scores (% presence) were re-calculated on the basis of a sample population including only flotation samples that contained charcoal (other quantification methods employed by Neef in the analysis of the Basta charcoals such as % frequency measured by volume (ml) and % ubiquity calculated on the basis of all archaeobotanical samples including those that did not contain charcoal, were not taken into account for the purpose of the present study)).

Chrono-cultural horizons	**calibrated years BC**	**Regional cultural entities and subsistence economies**
Late Epipalaeolithic	~12,000-10,000	Natufian (Levant, south Anatolian coast), Epipalaeolithic of the northeastern Fertile Crescent (Taurus-Zagros arc): hunting-gathering.
Pre-Pottery Neolithic A (PPNA)	~9700-8700	Khiamian (northern, southern? Levant), early PPN of the northeastern Fertile Crescent: hunting-gathering. Mureybetian (northern Levant), Sultanian (southern Levant): hunting-gathering; pre-domestication cultivation. PPNA habitations at Göbekli Tepe, Çayönü (SE Anatolia): hunting-gathering (pre-domestication cultivation?)
Early PPNB (EPPNB)	~8700-8200	Northern Levant, southeast Anatolia, (persistence of the PPNA in the southern Levant?), early PPN of the northeastern Fertile Crescent, early Cypro-PPNB; earliest known Neolithic settlement in central Anatolia: pre-domestication or mixed cultivation, hunting-gathering, herding, first appearance of domesticated crop “packages”.
Middle PPNB (MPPNB)	~8200-7500	MPPNB cultures of the southern Levant, aceramic Neolithic cultures of the northern Levant, southeast and central Anatolia, Cyprus and the Zagros: diverse habitation patterns and subsistence practices observed region-wide.
Late PPNB (LPPNB)	~7500-7000	Late aceramic Neolithic cultures, southern Levantine “megasites”: establishment and expansion of mixed agro-pastoral economies based on cereals, pulses and caprine herding region-wide, completion of the plant domestication process, widespread adoption of domesticated crop “packages” in mixed agropastoral economies.
Pottery Neolithic	~7000-6000	Ceramic Neolithic cultures of Southwest Asia; widespread presence of small-scale village life based on agricultural and pastoral production.
Chalcolithic	~6000-4000	Halaf, Ubaid and Uruk cultures of Mesopotamian (in the southern Levant Chalcolithic cultures date ~5.5-3.6 ka cal. BC); widespread evidence for increasing craft production, metallurgy, settlement hierarchies and emergent social inequality.

Table 3.1: Summary of prehistoric chrono-cultural horizons and associated economic practices in Southwest Asia (modified after Asouti and Fuller 2013).

Early Central Anatolian periodisation	Timespan	Traditional terminology
ECA I	13 ka cal. BP - c. 9000 cal. BC	Epipalaeolithic
ECA II	~9000-late 8th millennium cal. BC	Aceramic Neolithic
ECA III	late 8th millennium-6000 cal. BC	Neolithic (early + late)
ECA IV	6000-5500 cal. BC	Early Chalcolithic
ECA V	5500-4000 cal. BC	Middle Chalcolithic

Table 3.2: Subdivision of prehistoric (Early Central Anatolian) periods in central Anatolia (modified after Özbaşaran and Buitenhuis 2002: Table 2).

Lab no.	Context	Date bp uncal	Cal BP 2σ range 95.4
OxA 16536	Grave 13	12,945 ± 55	16,159-15,071
OxA 16535	Grave 14	12,580 ± 55	15,180-14,246
BA 130239	BIA	11,445 ± 40	13,427-13,187
BA 130242	BIA	11,400 ± 45	13,386-13,147
BA 130241	BHL	11,190 ± 45	13,247-12,897

Table 3.3: Dates from Pınarbaşı Epipalaeolithic Site B (after Baird et al. 2013).

Site	Context	Lab.no.	Date BP	Error	cal BC 1 sigma	cal bc 2 sigma	Material
A	ABJ	OxA–5499	9050	80	8422-8012	8526-7966	charcoal
A	ABR	OxA–5500	9290	80	8634-8351	8721-8306	charcoal
A	ABU	OxA–5501	9140	80	8454-8280	8565-8235	charcoal
A	ADK	OZH786	8680	70	7781-7595	7941-7584	nutshell
A	ADK	OZH787	8860	70	8208-7871	8235-7751	nutshell
A	ADN	OZH789	8920	70	8326-7970	8277-7828	nutshell
A	ADN	OZH788	9060	60	8307-8232	8458-7996	nutshell
A	AER	OZN584	9300	60	8635-8456	8709-8333	nutshell
A	AFC	Wk29760	9536	36	9118-8785	9132-8755	nutshell
A	AFR	Wk29761	8918	34	8227-7988	8238-7965	*Celtis*
D	DCL	Wk34089	8845	41	8185-7835	8210-7790	nutshell
D	DCP	OZN583	8900	60	8220-7970	8250-7827	nutshell

Table 3.4: Dates from Pınarbaşı aceramic Neolithic Sites A and D.

Lab no.	Context	Date bp uncal	Cal BC 1σ 68
OxA 5504	BBA	7450 ± 70	6320 ± 70
OxA 5503	BAT	7145 ± 55	6020 ± 70
OxA 5502	BAI	5725 ± 65	4580 ± 80

Table 3.5: Dates from Pınarbaşı late Neolithic-Chalcolithic Site B (after Watkins 1996).

Trench	Feature	Lab.no.	Date BP	Error	cal BC 1 sigma	cal bc 2 sigma	Material detail
H	HFI	OZN585	8880	60	8166-7743	8205-7660	nutshell
H	HFN	Wk29762	8841	30	8173-7835	8204-7794	nutshell (Prunoidae)
H	ZHB	Wk29763	8965	37	8271-8009	8278-7974	human bone; manual phalange
H	HQP	Wk34094	9107	39	8335-8270	8440-8245	einkorn grain
H	ZHM	BA120538	9000	25	8270-8238	8285-8230	human bone
H	ZHF	BA120539	8875	25	8200-7960	8230-7950	human bone
H	ZHP	BA120540	8945	30	8250-7990	8280-7990	human bone
H	ZHJ	BA120541	8980	25	8260-8220	8280-7990	human bone
H	HTG	BA120542	8805	30	7960-7790	8170-7730	human bone
M	MFI	Wk34093	9053	38	8290-8250	8305-8230	einkorn
K	KVC	Wk34092	8939	35	8245-7995	8255-7965	nutshell
K	ZKO	BA120536	8975	30	8270-8205	8280-7980	human bone

Table 3.6: Dates from Boncuklu trenches K, M and H.

Lab no.	Context	Date BP	Cal BC 1σ 68
HU 11	phase 5, near basal layers	8584 ± 65	7640 ± 70
HU 12	basal layer	8543 ± 66	7590 ± 60
BM 1667R	trench 49L/162F2	8480 ± 110	7500 ± 110
BM 1662R	trench 49L/148F	8460 ± 110	7480 ± 110
HU 9	phase 1-2, near summit	7874 ± 70	6800 ± 140

Table 3.7: Dates from Can Hasan III aceramic Neolithic levels (after Thissen 2002).

Levels			
Mellaart levels	**Hodder phases**	**Phases (according to ceramic tradition)**	**Dates cal BC**
0	TP.**S** TP.**R**	Late Ceramic Neolithic	6400-6000
I	TP.**Q**		
II	TP.**P** TP.**O**		
III	TP.**N** TP.**M** South **T** - 4040.J		
IV	South **S** - 4040.J		
V	South **R** - 4040.I South **Q** - 4040.H South **P** - 4040.H	Middle Ceramic Neolithic	
VIA	South **O** - 4040.G		6500-6400
VIB	South **N** - 4040.G		
VII	South **M** - 4040.G	Early Ceramic Neolithic	6700-6500
VIII	South **L** - 4040.F		
IX	South **K** - 4040.F		7300-6800
X	South **J**		
XI	South **I**		
XII	South **H**		
Pre-XII	**G**1,**G**2,**G**3,**G**4	Aceramic	

Table 3.8: New provisional phasing, pottery stratigraphy and associated radiocarbon dates for all excavated levels at Çatalhöyük.

Short-term deposits	Long-term deposits
Primary refuse (e.g., hearths and fire installations, destruction levels).	Secondary refuse (charcoals likely to derive from external, non-domestic areas such as middens, fills, etc.)
Composition of charcoal assemblage may not reflect long-term, established patterns of fuel selection and consumption but instead the remains of their last episode of use.	Composition of charcoal assemblage likely to reflect lasting patterns of firewood selection and consumption.
May furnish important information on the structure and function of particular hearth types and on aspects of wood use (e.g., choice of building materials and woodworking).	May maximise the potential of the analysis for palaeoenvironmental reconstruction.
May have been subject to diverse post-depositional alterations.	May allow a more precise evaluation of the effect of sedimentary conditions on overall charcoal preservation.

Table 4.1: Properties of primary fuel waste ("Short-term deposits") and dispersed ("Long-term deposits") contexts for anthracological analysis (after Asouti and Austin 2005).

	High density woodland vegetation	**Low density woodland vegetation**
Predicted Fuel Economy	Selective	Non-selective
Predicted composition of anthracological assemblage	Preferred taxa dominate fuel wood use, possibly also low diversity.	All available taxa are used; more diverse and even distribution of species abundance.
Inferred location of fuel wood collection zones	Bulk fuel collected close to habitation site; wood collectors very rarely travel longer distances to collect desired taxa. If there are fluctuations in the availability and density of preferred taxa, then less desirable taxa are used as fuel. Heavily focused on the use of dead (or dry wood). Occasional use of “greenwood”.	Possibly some distance away from the site, as well as in the vicinity of the habitation. Dead wood used when available, alongside “greenwood”.
PLE applicable?	**No**	**Yes**

Table 4.2: PLE model of fuel wood collection according to Shackleton and Prins (1992) introducing the distinction between selective and non-selective fuel wood economies, and tying them to the per capita fuel wood availability and density of woodland vegetation in close proximity to habitation sites.

Taxon	**Family**	**Dung**	**Arable**	**Wetland**	**Other dry**
Heliotropium	Boraginaceae	+	+		+
Chenopodium	Chenopodiaceae	+	+		+
Salsola	Chenopodiaceae	+			
Suaeda	Chenopodiaceae	?	+		+
Beta	Chenopodiaceae	+	+		+
Helianthemum	Cistaceae	+			+
Artemisia	Compositae	+	+		+
Bolboschoenus glaucus	Cyperaceae	+		+	
Carex	Cyperaceae	+	+	+	+
Cyperaceae	Cyperaceae	?		+	
Aeluropus	Gramineae	+		+	+
Crypsis	Gramineae	?		+	+
Sporobolus	Gramineae	+			
Juncus	Juncaceae	+		+	
Ziziphora	Labiatae	+			+
Leguminosae (small)	Leguminosae	+	+		+
Polygonum aviculare	Polygonaceae	+			+
Potamogeton	Potamogetonaceae	?	+		

Table 5.1: Dung-derived seed taxa from Çatalhöyük and their habitat types (after Bogaard et al. 2013, Filipović 2014).

Context	**BHK**	**BIA**	**BIB**	**BID**	**BIE**	**BIF**	**BIG**	**BIH**	**BIK**	**BIN**	**BIO**	**BIP**	**BIQ**	**ZBF**	
Sample no	**5013**	**4055**	**4056**	**4084**	**4086**	**4081**	**4087**	**4092**	**4097**	**4124**	**4129**	**4122**	**4123**	**5008**	
Charcoal weight (>2mm) (g)	0.018	0.155	0.58	0.25	0.092	0.037	0.058	0.043	0.141	0.005	0.009	0.032	0.025	0.022	
Sediment volume (l)	**19**	**101**	**25**	**38**	**73**	**47**	**10**	**50**	**48**	**20**	**10**	**26**	**24**	**22**	
Charcoal density (g/l)	0.0009	0.0015	0.0232	0.0066	0.0013	0.0008	0.0058	0.0009	0.0029	0.0003	0.0009	0.0012	0.0010	0.0010	
Context type	Dispersed occupation deposit	Dispersed occupation deposit	Midden-like fill of pit	Midden-like fill of pit	Dispersed occupation deposit	Dispersed occupation deposit	Dispersed occupation deposit	Dispersed occupation deposit	Dispersed occupation deposit	Dispersed occupation deposit	Fire feature/ash deposit	Dispersed occupation deposit	Dispersed occupation deposit	Fill of burial cut	**Total**
Juniperus		2	2	7	8	10		17		1	4	3	3		**57**
Amygdalus	1	28		33	2	1	8	5	9	1		6		1	**95**
Pistacia	1	2	1	1		1			1						**7**
Maloideae		7	1		8	4				1					**21**
Celtis			1	1											**2**
Ulmaceae			1												**1**
Salicaceae			1												**1**
Fraxinus							3								**3**
Total Identified	**2**	**39**	**7**	**42**	**18**	**16**	**11**	**22**	**10**	**3**	**4**	**9**	**3**	**1**	**187**
Indeterminate	***1***	***18***	***6***	***10***	***7***	***2***	***3***	***1***	***3***	***1***		***3***		***1***	***56***

Table 5.2: Wood charcoal fragment counts, weights (g), sediment volumes (l) and wood charcoal densities (g/l) from flotation samples taken at Pınarbaşı Site B (Epipalaeolithic)

Pınarbaşı Site B (Epipalaeolithic) dispersed contexts				
	Fragment count	**Ubiquity**	**% C**	**% U**
Juniperus	53	9	28.96	69
Amygdalus	95	11	51.91	85
Pistacia	7	6	3.83	46
Maloideae	21	5	11.48	38
Celtis	2	2	1.09	15
Ulmaceae	1	1	0.55	8
Salicaceae	1	1	0.55	8
Fraxinus	3	1	1.64	8
Total Identified	**183**	**(N=13)**	**100.00**	

Table 5.3: Summary fragment counts, ubiquity (sample presence), percentage fragment counts (% C) and ubiquity scores (% U) for all taxa found in Pınarbaşı Site B (Epipalaeolithic) dispersed contexts (i.e., excluding BIO sample 4129: fire feature).

Context	**AEJ**	**AHM**	**ADJ**	**ADV**	**AEB**	**AEI**	**AEL**	**AEM**	**AER**	**AEV**	**AFC**	**AFE**
Sample No	**143**	**309**	**10**	**87**	**158**	**142**	**146**	**147**	**151**	**153**	**192**	**183**
Charcoal weight (>2mm) (g)	0.105	0.091	0.002	0.003	0.2	0.134	0.032	0.132	0.193	0.321	0.169	0.108
Sediment volume (*l*)	**50**	**98**	**98**	**24**	**107**	**115**	**26**	**62**	**68**	**30**	**68**	**20**
Charcoal density (g/l)	0.0021	0.0009	0.0000	0.0001	0.0019	0.0012	0.0012	0.0021	0.0028	0.0107	0.0025	0.0054
Context type	External fill	Floor deposit	External fill	External fill	Structural debris	External fill	Floor deposit	Floor deposit	External fill	External fill	External fill	External fill
Juniperus												
Quercus									1			
Amygdalus	8	8	2	1	24	11	1	7	22	11	28	11
Pistacia												
Total Identified	**8**	**8**	**2**	**1**	**24**	**11**	**1**	**7**	**23**	**11**	**28**	**11**
Indeterminate	*2*		*2*		*26*	*10*	*11*	*11*	*13*	*9*	*29*	*1*

Context	**AFI**	**AFJ**	**AFM**	**AFR**	**DCZ**	**DCR**	**DCH**	**DCU**	**DCP**	**DGC**	**DCL**	
Sample No	**214**	**215**	**218**	**221**	**210**	**201**	**163**	**181**	**174**	**267**	**168**	
Charcoal weight (>2mm) (g)	0.638	0.219	0.009	0.194	0.002	0.006	0.089	0.042	0.118	0.087	0.379	
Sediment volume (*l*)	**61**	**75**	**118.5**	**50**	**2**	**14**	**74**	**57**	**125**	**12**	**204**	
Charcoal density (g/l)	0.0105	0.0029	0.0001	0.0039	0.0010	0.0004	0.0012	0.0007	0.0009	0.0073	0.0019	
Context type	External fill	External fill	External fill	Floor deposit	Floor deposit	Fill	Fill	Fill	External fill	Floor deposit	Midden	**Total**
Juniperus										1		**1**
Quercus						2						**3**
Amygdalus	63	35	3	4	1	2	18	16	15	3	6	**300**
Pistacia									2			**2**
Total Identified	**63**	**35**	**3**	**4**	**1**	**4**	**18**	**16**	**17**	**4**	**6**	**306**
Indeterminate	*10*	*13*				*1*	*4*	*14*	*13*	*1*	*2*	***172***

Table 5.4: Wood charcoal fragment counts, weights (g), sediment volumes (l) and wood charcoal densities (g/l) from flotation samples taken at Pınarbaşı Sites A and D (aceramic Neolithic).

Pınarbaşı Sites A, D (Early/Aceramic Neolithic) dispersed contexts				
	Fragment count	**Ubiquity**	**% C**	**% U**
Juniperus	1	1	0.33	4
Quercus	3	2	0.98	9
Amygdalus	300	23	98.04	100
Pistacia	2	1	0.65	4
Total Identified	**306**	**(N=23)**	**100.00**	

Table 5.5: Summary fragment counts, ubiquity (sample presence), percentage fragment counts (% C) and ubiquity scores (% U) for all taxa found in Pınarbaşı Sites A and D (aceramic Neolithic) dispersed contexts analysed in the present study.

Sample No	**105.15 /79F**	**104.1 /27F**	**101.1 /15F**	**105.5 /29F**	**105.7 /5F**	**109.14**	**110.6 /198F**	**109.17 /118F**	**107.34 /172F**	**107.17 /C62**	**107.17 /62F**	**110.11 /107W**	**110.19 /121W**
Charcoal weight (>2mm) (g)	0.560	0.370	0.290	0.430	0.330	0.140	0.290	0.080	0.450		0.090	0.180	0.050
Context type	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill
Phase	?	1	1	2	2	3E	3E	3E	3L	3L	3L	4	4
Pinus cf. *nigra*								1	7				
Juniperus		2	5	2	5				3	1			
Quercus				2	1		1		6		2		
Amygdalus	22	24	24	10	9	2	15	5	3	1		4	
Pistacia	8	7	3		10		4			2	1	5	1
Maloideae	1	1										4	
Salicaceae	1		2	2	1	3	7				5		2
Ulmaceae	17	11	14	32	23	9	20	12	7		5	3	2
Ulmus					1		2		2	1	2		
Celtis													
Chenopodiaceae	1												
Leguminosae		5		2									
Ulmaceae/Anacardiaceae									4	1		3	
Capparis												1	
Indet. gymnosperm							1						
Indet. twig			1										
Indet. bark													
cf. dicot stem			1										
Total Identified	**50**	**50**	**50**	**50**	**50**	**14**	**50**	**18**	**32**	**6**	**15**	**20**	**5**
Indeterminate	***16***	***6***	***4***	***4***	***3***	***6***	***5***	***3***	***5***		***1***	***2***	***1***

Table 5.6: Charcoal fragment counts and weights (g) from samples taken at Can Hasan III (aceramic Neolithic) *(continued overleaf*

Sample No	**110.20 /122W**	**110.2 /149W**	**110.20 /158W**	**110.13 /108W**	**110.22 /160F**	**110.18 /155F**	**110.8 /142F**	**110.3 /132F**	**111.2 /165F**	**110.4 /133**	**105.34 /47W**	**105.38**	
Charcoal weight (>2mm) (g)	0.040			0.030	0.320	0.070	0.360	0.130	0.019				
Context type	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Fill	Hearth fill	Hearth fill	
Phase	4	4	4	4	5	5	6	6	6	6	?	2	**Total**
Pinus cf. *nigra*													**8**
Juniperus			1				1	1					**21**
Quercus					1	2	1		1				**17**
Amygdalus		8	4		7		21	4	20	4	2	1	**190**
Pistacia	1	19	9	1	17	2	3	3	2	11		1	**110**
Maloideae		1											**7**
Salicaceae					1	1	2	2	4				**33**
Ulmaceae		14	10		14	1	14	4	7	8		9	**236**
Ulmus	1	1	1					1					**12**
Celtis		2											**2**
Chenopodiaceae					1								**2**
Leguminosae													**7**
Ulmaceae/Anacardiaceae				1	3		8		1				**21**
Capparis					1								**2**
Indet. gymnosperm													**1**
Indet. twig								1					**2**
Indet. bark		3											**3**
cf. dicot stem													**1**
Total Identified	**2**	**48**	**25**	**2**	**45**	**6**	**50**	**16**	**35**	**23**	**2**	**11**	**675**
Indeterminate		***2***	***10***		***22***	***4***	***12***		***4***	***9***	***1***	***6***	***126***

(continued from previous page) **Table 5.6**: Charcoal fragment counts and weights (g) from samples taken at Can Hasan III (aceramic Neolithic)

Can Hasan III dispersed contexts				
	Fragment count	**Ubiquity**	**% C**	**% U**
Pinus cf. *nigra*	8	2	1.22	9
Juniperus	21	9	3.21	39
Quercus	17	9	2.60	39
Amygdalus	187	18	28.59	78
Pistacia	109	19	16.67	83
Maloideae	7	4	1.07	17
Salicaceae	33	13	5.05	57
Ulmaceae	227	20	34.71	87
Ulmus	12	9	1.83	39
Celtis	2	1	0.31	4
Chenopodiaceae	2	2	0.31	9
Leguminosae	7	2	1.07	9
Ulmaceae/Anacardiaceae	21	7	3.21	30
Capparis	2	2	0.31	9
Total Identified	**654**	**(N=23)**	**100.00**	

Table 5.7: Summary fragment counts, ubiquity (sample presence), percentage fragment counts (% C) and ubiquity scores (% U) for all taxa found in Can Hasan III aceramic Neolithic contexts (all classified as “dispersed” contexts).

Context	**KRK**	**ZKM**	**KSU**	**KHO**	**KAE**	**KYS**	**KIC**	**KKY**	**KAN**	**KAJ**	**KJD**	**HFW**	**HBH**	**HAU**	**HAY**
Sample No	**915**	**900**	**955**	**611**	**10, 23, 26**	**1184**	**624**	**688**	**27**	**9**	**646**	**1971**	**713**	**707**	**711**
Charcoal weight (>2mm)	0.126	0.510	0.017	0.012	0.008	0.003	0.151	0.015	0.027	0.046	0.012	0.032	0.002	0.020	0.080
Sediment volume (l)	**17**	**119**	**8**	**5**	**45**	**18**	**13**	**2**	**24**	**10**	**1**	**38**	**41**	**26**	**33**
Charcoal density (g/l)	0.0074	0.0043	0.0021	0.0024	0.0002	0.0002	0.0116	0.0075	0.0011	0.0046	0.0120	0.0008	0.00005	0.0008	0.0024
Context type	Bld. debris /infill	Burial fill	Bld. debris /infill	Bld. debris /infill	Bld. debris /infill	Bld. debris /infill	Bld. debris /infill	Bld. debris /infill	Bld. debris /infill	Floor deposit	Bld. debris /infill	Midden	Midden	Midden	Midden
Pinus cf. *nigra*															
Juniperus		1		1		1									
Quercus		2										1			
Amygdalus	2	10	1		2										1
Pistacia		24		4											
Prunus															
Salicaceae	2	5	4		2	2	9	5		4	5	1	1	3	
Ulmaceae															
Fraxinus															
Tamarix															
Artemisia									3	1					
Chenopodiaceae								1							
Leguminosae															
Capparis															
Ephedra															
cf. *Arbutus*															
cf. *Paliurus/Ziziphus*															
cf. Euphorbiaceae															
cf. Maloideae															
cf. Anacardiaceae															
Indet. gymnosperm															
Indet. twig															
Indet. root wood															
cf. dicot stem								1		3					
Total Identified	**4**	**42**	**5**	**5**	**4**	**3**	**9**	**7**	**3**	**8**	**5**	**2**	**1**	**3**	**1**
Indeterminate		***7***	***2***		***7***			***3***	***2***			***1***	***1***		***1***

Table 5.8: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from flotation samples taken at Boncuklu *(continued overleaf)*

Context	**HLL**	**HLS**	**HFN**	**HBG**	**HFI**	**HFM**	**HFK**	**HCF**	**HCE**	**HRN**	**HTG**	**HVD**	**HVE**	**HVP**	**HTE**
Sample No	**1243**	**1247**	**840**	**714**	**835**	**841**	**837**	**730**	**728**	**1569**	**1589**	**1752**	**1755**	**1835**	**1570**
Charcoal weight (>2mm)	0.052	0.091	0.057	0.017	0.052	0.078	0.056	0.057	0.141	0.416	0.087	0.378	0.065	0.361	0.139
Sediment volume (l)	**13**	**15**	**28**	**35**	**55**	**35**	**18**	**76**	**30**	**125**	**19**	**197**	**36**	**54**	**16**
Charcoal density (g/l)	0.0040	0.0061	0.0020	0.0005	0.0009	0.0022	0.0031	0.0008	0.0047	0.0033	0.0046	0.0019	0.0018	0.0067	0.0087
Context type	Bld. debris /infill	Bld. debris /infill	Floor deposit	Midden	Bld. debris /infill	Midden	Floor deposit	Midden	Floor deposit	Midden	Midden	Midden	Midden	Midden	Bld. debris /infill
Pinus cf. *nigra*															
Juniperus															
Quercus					5					1			1		
Amygdalus	2		1			5				1	1	3	1	1	
Pistacia										1	1				
Prunus		1													
Salicaceae	8	13		3	3	3	2	4	7	17	13	7	9	37	7
Ulmaceae								1							
Fraxinus														6	
Tamarix															
Artemisia														1	
Chenopodiaceae										1					
Leguminosae					3							1			1
Capparis												1			1
Ephedra												1			
cf. *Arbutus*												1			
cf. *Paliurus/Ziziphus*															
cf. Euphorbiaceae												3	2		
cf. Maloideae															
cf. Anacardiaceae															
Indet. gymnosperm											1				
Indet. twig	1									1		1		1	
Indet. root wood															
cf. dicot stem										31	9	8	4		9
Total Identified	**11**	**14**	**1**	**3**	**11**	**8**	**2**	**5**	**7**	**53**	**25**	**26**	**17**	**46**	**18**
Indeterminate		***3***			***5***	***4***				***9***	***12***	***12***	***7***	***8***	***11***

(continued from previous page) **Table 5.8**: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from flotation samples taken at Boncuklu *(continued overleaf)*

Context	**HVU**	**HVT**	**HVJ**	**HVZ**	**NBQ**	**NBR**	**NAE**	**NAI**	**NJR**	**NJI**	**NHQ**	**NJV**	**NKJ**	**NJU**	**MBY**	**MBU**	**MBW**
Sample No	**1842**	**1836**	**1850**	**1847**	**1017**	**1015**	**1002**	**1014**	**1997**	**1889**	**1875**	**2001**	**2007**	**1993**	**189**	**196**	**188**
Charcoal weight (>2mm)	0.341	0.222	0.203	0.35	2.29	0.194	0.141	0.249	0.06	0.167	0.191	0.075	0.053	0.005	0.014	0.024	0.111
Sediment volume (l)	**32**	**18**	**49**	**28**	**206**	**31**	**162**	**79**	**15**	**43**	**14**	**15**	**16**	**18**	**16**	**19**	**42.5**
Charcoal density (g/l)	0.0107	0.0123	0.0041	0.0125	0.0111	0.0063	0.0009	0.0032	0.0040	0.0039	0.0136	0.0050	0.0033	0.0003	0.0009	0.0013	0.0026
Context type	Midden	Midden	Midden	Midden	Bld. debris /infill	Bld. debris /infill	Bld. debris /infill	Floor deposit	Midden	Midden	Midden	Midden	Floor deposit	Midden	Bld. debris /infill	Pit fill	Midden
Pinus cf. *nigra*																	
Juniperus									1			1					
Quercus					10		6		1	4							
Amygdalus		2	6	12	14	2	1	3	1	2	2		1		1		
Pistacia					4												
Prunus					1		3	1									
Salicaceae	35	19	12	21	86	5	13	9	3	10	6	10	2	1	3	2	11
Ulmaceae					1		1			2		1					
Fraxinus	1					2											
Tamarix							1	21	1	1		1		1			
Artemisia									1								
Chenopodiaceae	1																
Leguminosae		2			2	20	6						1				
Capparis	2			1													
Ephedra																	
cf. *Arbutus*																	
cf. *Paliurus/Ziziphus*	2			1						1		1		2			
cf. Euphorbiaceae	1							1	1	2							
cf. Maloideae	1																
cf. Anacardiaceae					1												
Indet. gymnosperm																	
Indet. twig	1		2		4					1							
Indet. root wood													1				
cf. dicot stem	4	2	1		7		2	2	2	2							
Total Identified	**48**	**25**	**21**	**35**	**130**	**29**	**33**	**37**	**11**	**25**	**8**	**14**	**5**	**4**	**4**	**2**	**11**
Indeterminate	***14***	***10***	***4***	***5***	***40***	***11***	***11***	***7***	***5***	***10***		***6***	***3***	***5***		***4***	

(continued from previous page) **Table 5.8**: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from flotation samples taken at Boncuklu *(continued overleaf)*

Context	**MFR**	**MEL**	**MDC**	**MFV**	**MBG**	**MFL**	**MAG**	**MFZ**	**MFI**	**MPF**	**MQN**	**MMA**	**MMC**	**MMB**	**MKU**
Sample No	**355**	**331**	**307**	**376**	**361**	**349**	**36**	**360**	**346**	**1982**	**2071**	**1733**	**1735**	**1739**	**1974**
Charcoal weight (>2mm)	0.008	0.03	0.023	0.115	0.043	0.229	0.001	0.26	0.144	0.038	0.253	0.049	0.128	0.108	0.246
Sediment volume (l)	**10**	**9**	**18**	**21**	**6**	**22**	**5**	**41**	**52**	**13**	**33**	**25**	**44**	**192**	**5**
Charcoal density (g/l)	0.0008	0.0033	0.0013	0.0055	0.0072	0.0104	0.0002	0.0063	0.0028	0.0029	0.0077	0.0020	0.0029	0.0006	0.0492
Context type	Bld. debris /infill	Midden	Midden	Bld. debris /infill	Bld. debris /infill	Midden	Floor deposit	Bld. debris /infill	Midden	Floor deposit	Bld. debris /infill	Midden	Midden	Midden	Building debris /infill
Pinus cf. *nigra*						1									
Juniperus												1			
Quercus								1						8	
Amygdalus														2	
Pistacia														2	
Prunus															
Salicaceae	2	3	6	3	3	15	1	7	7	13	8	9	16	27	6
Ulmaceae															
Fraxinus															
Tamarix												2	3	3	
Artemisia															
Chenopodiaceae															
Leguminosae			1												
Capparis														1	
Ephedra															
cf. *Arbutus*															
cf. *Paliurus/Ziziphus*															
cf. Euphorbiaceae															
cf. Maloideae															
cf. Anacardiaceae															
Indet. gymnosperm															
Indet. twig									1				1		
Indet. root wood														1	
cf. dicot stem													1		
Total Identified	**2**	**3**	**7**	**3**	**3**	**16**	**1**	**8**	**8**	**13**	**8**	**12**	**21**	**44**	**6**
Indeterminate		***1***	***3***	***3***		***1***			***4***			***1***	***8***	***12***	

(continued from previous page) **Table 5.8**: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from flotation samples taken at Boncuklu *(continued overleaf*

Context	**MKC**	**MPN**	**MPD**	**MNZ**	**HHBJ**	**HHBM**	**HHBD**	**NFA**	**NCK**	**MPA**	**HDF**	**KCA**	**MAH**	
Sample No	**1734**	**2079**	**1979**	**2084**	**2037**	**2038**	**2031**	**1615**	**1461**	**1977**	**746**	**222**	**37**	
Charcoal weight (>2mm)	0.157	0.657	0.233	0.134	0.044	0.146	0.178	0.059	0.021	0.033	0.007	0.003	0.129	
Sediment volume (l)	**68**	**235**	**29**	**83**	**27**	**16**	**19**	**4**	**18**	**14**	**7**	**11**	**2**	
Charcoal density (g/l)	0.0023	0.0028	0.0080	0.0016	0.0016	0.0091	0.0094	0.0148	0.0012	0.0024	0.0010	0.0003	0.0645	
Context type	Midden	Midden	Pit fill	Midden	Fire feature	Fire feature	Fire feature	Fire feature	Fire feature	Fire feature	Fire feature	Fire feature	Fire feature	**Total**
Pinus cf. *nigra*														**1**
Juniperus		4											1	**11**
Quercus			1	3					1				3	**48**
Amygdalus		4		1			1			1		1	1	**89**
Pistacia							2	3						**41**
Prunus														**6**
Salicaceae	13	23	6	17	12	5	11		1	7	1		11	**657**
Ulmaceae									2					**8**
Fraxinus						1								**10**
Tamarix	1	1	1					1		1				**39**
Artemisia		1											5	**12**
Chenopodiaceae		1											2	**6**
Leguminosae		1	2											**40**
Capparis														**6**
Ephedra														**1**
cf. *Arbutus*														**1**
cf. *Paliurus/Ziziphus*		1												**8**
cf. Euphorbiaceae		3												**13**
cf. Maloideae														**1**
cf. Anacardiaceae														**1**
Indet. gymnosperm														**1**
Indet. twig			1	1									2	**18**
Indet. root wood														**2**
cf. dicot stem	1	3	2	5			1							**100**
Total Identified	**15**	**42**	**13**	**27**	**12**	**6**	**15**	**4**	**4**	**9**	**1**	**1**	**25**	**1120**
Indeterminate	***6***	***10***	***8***	***3***	***1***	***9***	***1***	***2***	***4***	***1***				***310***

(continued from previous page) **Table 5.8**: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from flotation samples taken at Boncuklu.

Boncuklu höyük dispersed contexts																
Trench	**K**				**H**				**N**				**M**			
	C	**% C**	**U**	**% U**	**C**	**% C**	**U**	**% U**	**C**	**% C**	**U**	**% U**	**C**	**% C**	**U**	**% U**
Pinus cf. *nigra*													1	0.40	1	4.55
Juniperus	3	3.30	3	27.27					2	0.73	2	20	5	1.98	2	9.09
Quercus	2	2.20	1	9.09	8	2.61	4	17.39	21	7.64	4	40	13	5.16	4	18.18
Amygdalus	15	16.48	4	36.36	36	11.73	12	52.17	26	9.45	8	80	8	3.17	4	18.18
Pistacia	28	30.77	2	18.18	2	0.65	2	8.70	4	1.45	1	10	2	0.79	1	4.55
Prunus					1	0.33	1	4.35	5	1.82	3	30				
Salicaceae	38	41.76	9	81.82	225	73.29	21	91.30	145	52.73	10	100	201	79.76	22	100
Ulmaceae					1	0.33	1	4.35	5	1.82	4	40				
Fraxinus					7	2.28	2	8.70	2	0.73	1	10				
Tamarix									26	9.45	6	60	11	4.37	6	27.27
Artemisia	4	4.40	2	18.18	1	0.33	1	4.35	1	0.36	1	10	1	0.40	1	4.55
Chenopodiaceae	1	1.10	1	9.09	2	0.65	2	8.70					1	0.40	1	4.55
Leguminosae					7	2.28	4	17.39	29	10.55	4	40	4	1.59	3	13.64
Capparis					5	1.63	4	17.39					1	0.40	1	4.55
Ephedra					1	0.33	1	4.35								
cf. *Arbutus*					1	0.33	1	4.35								
cf. *Paliurus/Ziziphus*					3	0.98	2	8.70	4	1.45	3	30	1	0.40	1	4.55
cf. Euphorbiaceae					6	1.95	3	13.04	4	1.45	3	30	3	1.19	1	4.55
cf. Maloideae					1	0.33	1	4.35								
cf. Anacardiaceae									1	0.36	1	10				
Total Identified	**91**	**100.00**	**(N=11)**		**307**	**100.00**	**(N=23)**		**275**	**100.00**	**(N=10)**		**252**	**100.00**	**(N=22)**	

Table 5.9: Quantified charcoal frequencies from Boncuklu höyük dispersed contexts grouped by excavated area (Trenches K, H, N and M) including fragment counts (C), percentage fragment counts (% C), ubiquity (number of contexts in which each taxon was present) (U), and ubiquity scores (% U).

Unit No	**4879**	**4869**	**4866**	**30625**	**1835**	**1845**	**1612**	**4121**	**4102**	**1099**	**1544**	**20379**	**20807**
Flot No	**3297**	**3151, 3148, 3149**	**3133, 3137**	**10743**	**639**	**674**	**345**	**2346**	**2315**	**173**	**281**	**10230, 10367**	**10431**
Phase	South G	South G	South G-H	South H	South K	South K	South K	South L	South L	South L	South M	South O	South O
Charcoal weight (>4mm) (g)	1.844	4.683	16.288	35.4	16.283	29.571	15.119	16.115	11.776	45.475	4.563	37.582	4.06
Sediment volume (l)	**33**	**91**	**63**	**32**	**34**	**33**	**17**	**30**	**29**	**35**	**17**	**32.5**	**25**
Charcoal density (g/l)	0.0559	0.0515	0.2585	1.1063	0.4789	0.8961	0.8894	0.5372	0.4061	1.2993	0.2684	1.1564	0.1624
Context type	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden
Juniperus	3			1	1	2	5	4	1		1	25	11
Quercus		9	24	25	17	15	27	18	36	28	23	37	41
Amygdalus	1	1		4		1						7	3
Pistacia	6				2	1	10					2	
Prunus			2				2		1				
Maloideae		1	4	2	1	2	3	1	2				1
Anacardiaceae			1		1					1		1	3
Rhamnus				3									
Salicaceae	7	11	14	25	12	19	10	6	8	7	1	9	6
Ulmaceae	5	5		31	7	9	16	1		1		3	4
Ulmus	1	8	11	13	4	7	8	8	15	10	23	11	5
Celtis	11	14	10	9	12	10	12	11	8	6		1	
Fraxinus					1		2		1	18			
Acer					1								
Tamarix					1							1	
Chenopodiaceae			4	2			2	1		2			
Artemisia	1		1	4	5	2							
Leguminosae		1	2		7	5				1		2	
Labiateae							1						
Rosaceae						1							
cf. *Capparis*					2		1			1	1		
Indet. twig			2	3	1	1	1		3			1	1
Indet. bark				3									
cf. dicot stem											1		
Total Identified	**35**	**50**	**75**	**125**	**75**	**75**	**100**	**50**	**75**	**75**	**50**	**100**	**75**
Indeterminate	***19***	***16***	***19***	***9***	***26***	***15***	***12***	***10***	***18***	***8***	***8***	***9***	***1***

Table 5.10: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from Çatalhöyük East flotation samples (midden deposits) analysed in the present study *(continued overleaf)*

Unit No	**12519**	**18139**	**19107**	**19116**	**14551**	**11397**	**15743**	**11376**	**17039**	**17017**	**16590**	**17058**	**17047**
Flot No	**6771**	**8828**	**9204**	**9215**	**7330**	**6494**	**7592**	**6123**	**8183**	**8088**	**8056**	**8318, 8276**	**8224**
Phase	South P	South P	South P	South P	South Q	South Q	South Q	South Q	South R	South R	South R	South R	South R
Charcoal weight (>4mm) (g)	159.463	78.868	32.094	44.486	32.096	13.165	3.912	9.522	12.113	6.992	6.148	3.586	5.956
Sediment volume (l)	**26**	**22**	**22**	**32**	**24**	**29**	**22**	**26**	**32**	**17**	**26**	**26**	**24**
Charcoal density (g/l)	6.1332	3.5849	1.4588	1.3902	1.3373	0.4540	0.1778	0.3662	0.3785	0.4113	0.2365	0.1379	0.2482
Context type	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden
Juniperus	2	1		2	35	6	6	13	19	18	16	26	29
Quercus	42	45	24	33	11	15	12	24	6	6	11	10	13
Amygdalus		1	2		3	2		3	8	7	3	2	2
Pistacia	1			2		1		9		6	1		
Prunus	1			1									
Maloideae	3	1	2										
Anacardiaceae													
Rhamnus													
Salicaceae	35	22	13	7	4	10	1	5	1		2		
Ulmaceae	19	3	14	16	4	10	1	9	6	7	5	3	2
Ulmus	12	1	7	2	1	4	3	3			3	1	
Celtis	6		5	3		1		4	1		3	1	2
Fraxinus					15		2	3	9	6	6	7	11
Acer													1
Tamarix			2	1	1								
Chenopodiaceae													
Artemisia	2		4					2					
Leguminosae		1											
Labiateae													
Rosaceae													
cf. *Capparis*			2										
Indet. twig	1			7									
Indet. bark				1	1	1							
cf. dicot stem	1												
Total Identified	**125**	**75**	**75**	**75**	**75**	**50**	**25**	**75**	**50**	**50**	**50**	**50**	**60**
Indeterminate	***20***	***7***	***21***	***8***	***6***	***9***		***4***	***7***	***7***	***8***	***4***	***5***

(continued from previous page) **Table 5.10**: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from Çatalhöyük East flotation samples (midden deposits) analysed in the present study *(continued overleaf)*

Unit No	**17032**	**16507**	**16568**	**16253**	**17369**	**14059**	**14028**	**17368**	**17373**	**15282**	**15281**	**13528**	**11528**	
Flot No	**8155**	**7860**	**8026**	**7830**	**8860**	**7059**	**7031**	**8858**	**8861**	**7616**	**7518**	**7648**	**5950**	
Phase	South R	South S	South S	South S	South T	South T	South T	South T	South T	TP N	TP O	TP P	TP R	
Charcoal weight (>4mm) (g)	1.471	11.432	2.309	0.693	14.668	2.158	1.634	0.507	0.44	21.476	19.432	5.505	8.783	
Sediment volume (l)	**5**	**19**	**26**	**18**	**58**	**24**	**26**	**30**	**30**	**20**	**22**	**16**	**20**	
Charcoal density (g/l)	0.2942	0.6017	0.0888	0.0385	0.2529	0.0899	0.0628	0.0169	0.0147	1.0738	0.8833	0.3441	0.4392	
Context type	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	Midden	**Total**
Juniperus	8	12	11	16	42	21	21	5	2	9	9	11	9	**403**
Quercus	7	15	5		4	13	4	1	6	4	7	10	10	**638**
Amygdalus	1	4	1	3	3	1	3	5		5		4	3	**83**
Pistacia		11		1	7	1	2	3				1		**67**
Prunus														**7**
Maloideae										1				**24**
Anacardiaceae														**7**
Rhamnus														**3**
Salicaceae									5	6	3	4	4	**257**
Ulmaceae	2	1	3			10			3	12	8	4	7	**231**
Ulmus						1				13	7	5	6	**193**
Celtis			1							6	9	7	7	**160**
Fraxinus	2	16	4	1	4	3	2			2	2	1	3	**121**
Acer														**2**
Tamarix														**6**
Chenopodiaceae														**11**
Artemisia		1								1	4			**27**
Leguminosae												3		**22**
Labiateae														**1**
Rosaceae														**1**
cf. *Capparis*														**7**
Indet. twig										1	1		1	**24**
Indet. bark														**6**
cf. dicot stem														**2**
Total Identified	**20**	**60**	**25**	**21**	**63**	**50**	**32**	**14**	**16**	**60**	**50**	**50**	**50**	**2306**
Indeterminate		***7***		***1***	***3***	***2***			***5***	***10***	***5***	***2***	***7***	***318***

(continued from previous page) **Table 5.10**: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from Çatalhöyük East flotation samples (midden deposits) analysed in the present study.

Unit no	**17082**	**18548**	**18199**	**18176**	**18194**	**18509**	**17396**	**16249**	**16570**	**18180**	**18181**	**18505**	**18608**
Flot no	**8326**	**9027**	**9026**	**8958**	**9016**	**8948**	**8922**	**7834**	**8019**	**8977**	**8982**	**8959**	**9047**
Phase	South P	South P	South P	South P	South P	South P	South P	South P	South P	South P	South P	South P	South P
Charcoal weight (>4mm) (g)	27.260	20.649	3.378	3.977	3.397	1.850	1.641	0.357	3.795	0.942	0.077	0.460	0.374
Sediment volume (l)	**25**	**10**	**16**	**6**	**5**	**4**	**2**	**25**	**28**	**6**	**2**	**2**	**2**
Charcoal density (g/l)	1.0904	2.0649	0.2111	0.6628	0.6794	0.4625	0.8205	0.0143	0.1355	0.1570	0.0385	0.2300	0.1870
Context type	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Ashy rake-out	Oven fill	Fire spot	Fire spot	Fire spot	Fire spot
Juniperus	5	3	3		2			3	4				
Quercus	23	18	14	25	28	19	18	7	13	14	2	11	5
Amygdalus				1			1	1	1				
Pistacia	1	1	3	1							1	1	
Prunus	1				1								
Salicaceae	17	6	7	2	9	2	1	1	2	4	2	2	
Ulmaceae	42	7	4	3	23	3	2			3		1	2
Ulmus	10	1		2	1					1			
Celtis	4	3					2		2				
Fraxinus			6										
Tamarix		1											
Artemisia	15		3			1				1			
Chenopodiaceae					2								
Leguminosae	3												
cf. *Capparis*													
Indet. twig	1				3								
Indet. bark	1			1				1					
Indet. root wood	1												
Dicot. stem					1								
Total Identified	**124**	**40**	**40**	**35**	**70**	**25**	**24**	**13**	**22**	**23**	**5**	**15**	**7**
Indeterminate	***8***	***1***	***1***	***2***		***5***		***2***	***3***	***2***	***1***	***3***	

Table 5.11: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from Çatalhöyük East flotation samples (primary fuel waste deposits) analysed in the present study *(continued overleaf)*

Unit no	**15782**	**15780**	**17084**	**16279**	**15771**	**17061**	**17324**	**17338**	**17334**	**17336**	**16223**	**14546**	**14537**
Flot no	**7756**	**7772**	**8328**	**7857**	**7742**	**8309**	**8418**	**8467**	**8429**	**8469**	**7801**	**7267**	**7291**
Phase	South P	South P	South P	South P	South P	South P	South P	South P	South P	South P	South P	South Q	South Q
Charcoal weight (>4mm) (g)	34.662	28.359	5.503	7.589	1.131	0.278	0.168	0.464	0.305	0.096	0.614	1.536	2.374
Sediment volume (l)	**6**	**55**	**30**	**2**	**6**	**13**	**1**	**2**	**2**	**1**	**1**	**1**	**8**
Charcoal density (g/l)	5.7770	0.5156	0.1834	3.7945	0.1885	0.0214	0.1680	0.2320	0.1525	0.0960	0.6140	1.5360	0.2968
Context type	Fire spot	Fire spot	Fire spot	Hearth fill	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot
Juniperus	7	2	6	2	41			8		2			10
Quercus	33	35	17	33	1	9	3	1	11	3	23	5	15
Amygdalus													1
Pistacia		1											
Prunus													
Salicaceae			5										10
Ulmaceae		2	2							2			2
Ulmus			4										
Celtis			5										
Fraxinus												20	2
Tamarix													
Artemisia													
Chenopodiaceae													
Leguminosae													
cf. *Capparis*			1										
Indet. twig													
Indet. bark													
Indet. root wood													
cf. dicot. stem													
Total Identified	**40**	**40**	**40**	**35**	**42**	**9**	**3**	**9**	**11**	**7**	**23**	**25**	**40**
Indeterminate		***2***	***3***	***1***				***1***		***2***			***2***

(continued from the previous page) **Table 5.11:** Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from Çatalhöyük East flotation samples (primary fuel waste deposits) analysed in the present study *(continued overleaf)*

Unit no	**14564**	**14548**	**14545**	**13373**	**13358**	**14547**	**17007**	**17029**	**17008**	**17057**	**17033**	**17044**	**16519**	
Flot no	**7293**	**7263**	**7264**	**6937**	**6793**	**7266**	**8087**	**8284**	**8095**	**8287**	**8149**	**8175**	**7925**	
Phase	South Q	South Q	South Q	South Q	South Q	South Q	South R	South R	South R	South R	South R	South R	South S	
Charcoal weight (>4mm) (g)	0.270	0.155	0.121	5.024	1.198	0.052	0.131	0.036	0.132	0.079	0.538	4.300	1.209	
Sediment volume (l)	**2**	**1**	**1**	**2**	**0.5**	**1**	**1**	**0.1**	**0.5**	**2**	**0.1**	**16**	**2**	
Charcoal density (g/l)	0.1350	0.1550	0.1210	2.5120	2.3960	0.0520	0.1310	0.3600	0.2640	0.0395	5.3800	0.2688	0.6045	
Context type	Fire spot	Fire spot	Fire spot	Oven fill	Hearth fill	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	Fire spot	**Total**
Juniperus	1	4	1	23	11		7	1	2	5	3	18		**174**
Quercus		3	2	4	25	2				2		3	25	**452**
Amygdalus										1				**6**
Pistacia														**9**
Prunus														**2**
Salicaceae														**70**
Ulmaceae												5		**103**
Ulmus											3			**22**
Celtis												2		**18**
Fraxinus			5	18								10		**61**
Tamarix														**1**
Artemisia												1		**21**
Chenopodiaceae														**2**
Leguminosae														**3**
cf. *Capparis*														**1**
Indet. twig														**4**
Indet. bark														**3**
Indet. root wood														**1**
cf. dicot. stem												1		**2**
Total Identified	**1**	**7**	**8**	**45**	**36**	**2**	**7**	**1**	**2**	**8**	**6**	**40**	**25**	**955**
Indeterminate	**1**									**5**		**4**		***49***

(continued from the previous page) **Table 5.11:** Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from Çatalhöyük East flotation samples (primary fuel waste deposits) analysed in the present study.

Unit No	9019	9014	9017	16981	16938	9030	6520	6513	2966	2960	16958	16950	3490	9049	9052	16951	
Flot No	**5701**	**5670**	**5695**	**10111**	**9600**	**5764**	**4207**	**4190**	**1598**	**1547**	**9564**	**9562**	**4131**	**5778**	**5779**	**9573**	
Phase	West	West	West	West	West	West	West	West	West	West	West	West	West	West	West	West	
Charcoal weight (>4mm) (g)	1.319	0.978	1.04	0.119	2.351	2.996	1.674	1.272	0.899	1.617	3.257	0.339	0.668	0.926	0.268	0.209	
Sediment volume (l)	**32**	**29**	**28**	**28**	**20**	**28**	**31**	**26**	**42**	**37**	**33**	**26**	**25**	**32**	**12**	**6**	
Charcoal density (g/l)	0.0412	0.0337	0.0371	0.0043	0.1176	0.1070	0.0540	0.0489	0.0214	0.0437	0.0987	0.0130	0.0267	0.0289	0.0223	0.0348	
Context	Midden	Midden	Midden	Midden	Building infill	Building infill	Building infill	Building infill	Floor deposit	Building infill	Building infill	Building infill	Hearth fill	Oven fill	Oven fill	Ashy rake-out	**Total**
Juniperus	14	9	8	3	46	40	15	20	14	12	4	13	5	6	2	11	**222**
Quercus		2			4		2	6	1		29	1		2			**47**
Amygdalus		1				1	4	1	2	4				2			**15**
Pistacia	1	3			1	1					3			2			**11**
Maloideae											1						**1**
Prunus										1			1				**2**
Salicaceae	3	1	3					1	4	2					1		**15**
Ulmaceae	9	6	16	1	5	23	15	9	8	23	13	1	2	8	2		**141**
Ulmus	2	1	1		1	1	2			3	3						**14**
Celtis	7		3			3		1									**14**
Fraxinus		7		1	1		1	2			1			1	1		**15**
Acer								1									**1**
Tamarix									1					2			**3**
Artemisia			5			2											**7**
Chenopodiaceae							1			1	1						**3**
Leguminosae							1	1	2		1				1		**6**
Indet. twig											1		2				**3**
Indet. bark							1							2			**3**
Total Identified	**36**	**30**	**36**	**5**	**58**	**71**	**42**	**42**	**32**	**46**	**57**	**15**	**10**	**25**	**7**	**11**	**523**
Indeterminate	***1***	***3***			***7***	***8***	***3***	***8***	***5***	***4***	***7***			***3***			***49***

Table 5.12: Charcoal fragment counts, weights (g), sediment volumes (l) and charcoal densities (g/l) from all Çatalhöyük West flotation samples analysed in the present study.

Site/Phase	**PB Epipal.**			**PB Acer. NL**			**PB Late NL**			**PB Chalco.**			**Can Hasan III**			**BK Trench K**		
	Total Frgmt C.	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**
Pinus cf. *nigra*													8	8				
Juniperus	53	53		1	1		3		3				21	21		3	3	
Quercus				3	3		1		1	1		1	17	17		2	2	
Amygdalus	95	95		346	300	46	2858		2858	683		683	187	187		15	15	
Pistacia	7	7		3	2	1	1355		1355	327		327	109	109		28	28	
Anacardiaceae																		
Prunus				3						1		1						
Maloideae	21	21								15		15	7	7				
Ulmaceae	1	1											227	227				
Ulmus													12	12				
Celtis	2	2					104		104	12		12	2	2				
Salicaceae	1	1											33	33		38	38	
Fraxinus	3	3					24		24	2		2						
Acer							1		1									
Tamarix							36		36	4		4						
Platanus																		
Alnus																		
Vitex																		
Labiateae																		
Rhamnus							1		1	20		20						
Artemisia				3		3	5		5	3		3				4	4	
Chenopodiaceae				1		1							2	2		1	1	
Leguminoseae				1		1	4		4				7	7				
Capparis							3		3				2	2				
Ephedra																		
Caprifoliaceae																		
Ficus carica																		
Clematis							7		7	1		1						
Rosaceae				5		5	49		49	3		3						
cf. *Arbutus*																		
cf. *Paliurus/Ziziphus*																		
cf. Euphorbiaceae																		
cf. Maloideae																		
Ulmaceae/Anacardiaceae													21	21				
Total Identified	**183**	**183**		**366**	**306**	**60**	**4451**		**4451**	**1072**		**1072**	**655**	**655**		**91**	**91**	
No of contexts/units	**13**	**13**		**25**	**23**	**2**	**28**		**28**	**8**		**8**				**11**	**11**	

Table 5.13a: Per phase summary fragment counts analysed by Kabukcu (CK), Asouti (EA) and combined summary fragment counts from all sites (Fragment counts from dispersed contexts studied in the present thesis (CK) and Asouti 2002, 2003, 2005, 2013 (EA)). (*continued overleaf*)

Site/Phase	**BK Trench H**			**BK Trench N**			**BK Trench M**			**Ch. South G**			**Ch. Souht G-H**			**Ch. South I**		
	Total Frgmt C.	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**
Pinus cf. *nigra*							1	1										
Juniperus				2	2		5	5		9	3	6	7	1	6	1		1
Quercus	8	8		21	21		13	13		31	9	22	651	49	602	384		384
Amygdalus	36	36		26	26		8	8		21	2	19	4	4		1		1
Pistacia	2	2		4	4		2	2		39	6	33	19		19	1		1
Anacardiaceae				1	1								1	1				
Prunus	1	1		5	5					1		1	2	2				
Maloideae										16	1	15	19	6	13	1		1
Ulmaceae	1	1		5	5					473	10	463	119	31	88	88		88
Ulmus										86	9	77	28	24	4	7		7
Celtis										132	25	107	126	19	107	12		12
Salicaceae	225	225		145	145		201	201		281	18	263	226	39	187	126		126
Fraxinus	7	7		2	2								1		1	1		1
Acer																		
Tamarix				26	26		11	11		3		3						
Platanus																		
Alnus																		
Vitex										2		2	2		2			
Labiateae										5		5				1		1
Rhamnus													3	3				
Artemisia	1	1		1	1		1	1		14	1	13	15	5	10			
Chenopodiaceae	2	2		0	0		1	1		7		7	9	6	3	2		2
Leguminoseae	7	7		29	29		4	4		1	1		8	2	6			
Capparis	5	5					1	1					1		1			
Ephedra	1	1								1		1						
Caprifoliaceae										1		1						
Ficus carica																		
Clematis																		
Rosaceae										3		3						
cf. *Arbutus*	1	1																
cf. *Paliurus/Ziziphus*	3	3		4	4		1	1										
cf. Euphorbiaceae	6	6		4	4		3	3										
cf. Maloideae	1	1																
Ulmaceae/Anacardiaceae																		
Total Identified	**307**	**307**		**275**	**275**		**252**	**252**		**1126**	**85**	**1041**	**1241**	**192**	**1049**	**625**		**625**
No of contexts/units	**23**	**23**		**10**	**10**		**23**	**23**		**18**	**2**	**16**	**13**	**2**	**11**	**6**		**6**

(*continued from previous page*) **Table 5.13a**: Per phase summary fragment counts analysed by Kabukcu (CK), Asouti (EA) and combined summary fragment counts from all sites (Fragment counts from dispersed contexts studied in the present thesis (CK) and Asouti 2002, 2003, 2005, 2013 (EA)). (*continued overleaf*)

Site/Phase	**Ch. South J**			**Ch. South K**			**Ch. South L**			**Ch. South M**			**Ch. South O**			**Ch. South P**		
	Total Frgmt C.	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**	**Total Frgmt C.**	**CK**	**EA**
Pinus cf. *nigra*																		
Juniperus	2		2	23	8	15	28	5	23	20	1	19	36	36		42	5	37
Quercus	130		130	371	59	312	636	82	554	253	23	230	78	78		270	144	126
Amygdalus	1		1	7		7	8		8	1		1	10	10		8	3	5
Pistacia	1		1	26	13	13	19		19	14		14	2	2		6	3	3
Anacardiaceae				1	1		1	1					4	4				
Prunus							8	1	7	2		2				2	2	
Maloideae	7		7	68	6	62	19	3	16	4		4	1	1		6	6	
Ulmaceae	26		26	110	32	78	61	2	59	5		5	7	7		96	52	44
Ulmus	2		2	37	19	18	70	33	37	38	23	15	16	16		22	22	
Celtis	3		3	67	34	33	69	25	44	11		11	1	1		17	14	3
Salicaceae	28		28	127	41	86	146	21	125	31	1	30	15	15		102	77	25
Fraxinus	12		12	7	3	4	24	19	5	2		2				3		3
Acer				2	1	1	5		5	2		2						
Tamarix				1	1		1		1	3		3	1	1		4	3	1
Platanus							1		1									
Alnus							1		1	2		2						
Vitex							4		4	1		1						
Labiateae	1		1	6	1	5	5		5	1		1						
Rhamnus																		
Artemisia				11	7	4	8		8	2		2				6	6	
Chenopodiaceae				10	2	8	18	3	15	3		3						
Leguminoseae				38	12	26	31	1	30	2		2	2	2		1	1	
Capparis				4	3	1	1	1		1	1					2	2	
Ephedra																		
Caprifoliaceae										1		1						
Ficus carica							1		1							1		1
Clematis																		
Rosaceae				1	1		1		1	1		1						
cf. *Arbutus*																		
cf. *Paliurus/Ziziphus*																		
cf. Euphorbiaceae																		
cf. Maloideae																		
Ulmaceae/Anacardiaceae																		
Total Identified	**213**		**213**	**917**	**244**	**673**	**1166**	**197**	**969**	**400**	**49**	**351**	**173**	**173**		**588**	**340**	**248**
No of contexts/units	**2**		**2**	**9**	**3**	**6**	**11**	**3**	**8**	**4**	**1**	**3**	**2**	**2**		**7**	**4**	**3**

(*continued from previous page*) **Table 5.13a**: Per phase summary fragment counts analysed by Kabukcu (CK), Asouti (EA) and combined summary fragment counts from all sites (Fragment counts from dispersed contexts studied in the present thesis (CK) and Asouti 2002, 2003, 2005, 2013 (EA)). (*continued overleaf*)

Site/Phase	Ch. South Q			Ch. South R			Ch. South S			Ch. South T			Ch. TP			Ch. West		
	Total Frgmt C	**CK**	**EA**	**Total Frgmt C**	**CK**	**EA**	**Total Frgmt C**	**CK**	**EA**	**Total Frgmt C**	**CK**	**EA**	**Total Frgmt C**	**CK**	**EA**	**Total Frgmt C**	**CK**	**EA**
Pinus cf. *nigra*																		
Juniperus	104	60	44	116	116		294	39	255	91	91		108	38	70	198	198	
Quercus	83	62	21	53	53		48	20	28	28	28		45	31	14	45	45	
Amygdalus	11	8	3	23	23		35	8	27	12	12		22	12	10	13	13	
Pistacia	10	10		7	7		15	12	3	13	13		23	1	22	9	9	
Anacardiaceae																		
Prunus																1	1	
Maloideae													1	1		1	1	
Ulmaceae	27	24	3	25	25		7	4	3	13	13		173	31	142	129	129	
Ulmus	11	11		4	4		4		4	1	1		76	31	45	14	14	
Celtis	5	5		7	7		1	1					39	29	10	14	14	
Salicaceae	21	20	1	3	3		2		2	5	5		58	17	41	14	14	
Fraxinus	23	20	3	41	41		28	21	7	9	9		18	8	10	13	13	
Acer				1	1		2		2							1	1	
Tamarix	1	1											3		3	1	1	
Platanus																		
Alnus																		
Vitex																		
Labiateae																		
Rhamnus																		
Artemisia	2	2					1	1					5	5		7	7	
Chenopodiaceae																3	3	
Leguminoseae													4	3	1	5	5	
Capparis																		
Ephedra																		
Caprifoliaceae																		
Ficus carica																		
Clematis																		
Rosaceae																		
cf. *Arbutus*																		
cf. *Paliurus/Ziziphus*																		
cf. Euphorbiaceae																		
cf. Maloideae																		
Ulmaceae/Anacardiaceae																		
Total Identified	**298**	**223**	**75**	**280**	**280**		**437**	**106**	**331**	**172**	**172**		**575**	**207**	**368**	**468**	**468**	
No of contexts/units	**6**	**4**	**2**	**6**	**6**		**7**	**3**	**4**	**5**	**5**		**9**	**4**	**5**	**12**	**12**	

(*continued from previous page*) **Table 5.13a**: Per phase summary fragment counts analysed by Kabukcu (CK), Asouti (EA) and combined summary fragment counts from all sites (Fragment counts from dispersed contexts studied in the present thesis (CK) and Asouti 2002, 2003, 2005, 2013 (EA)).

Site/Phase	**PB Epipal.**			**Can Hasan III**			**BK**			**Ch. South G**			**Ch. South H**			**Ch. South M**		
	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA
Juniperus	4	4					1	1		3		3				16		16
Quercus							4	4		10		10	122		122	54		54
Amygdalus				3	3		4	4		8		8						
Pistacia				1	1		5	5		5		5				1		1
Prunus										1		1				1		1
Maloideae										8		8				7		7
Salicaceae							48	48		127		127	13		13	12		12
Ulmaceae				9	9		1	1		68		68	2		2	3		3
Ulmus										4		4				1		1
Celtis							1	1		26		26	1		1	2		2
Fraxinus							1	1		2		2				2		2
Tamarix							2	2		1		1				1		1
Artemisia							5	5		3		3						
Chenopodiaceae							2	2										
Leguminoseae																7		7
Capparis																		
Labiatae																		
Total Identified	**4**	**4**		**13**	**13**		**76**	**76**		**266**		**266**	**138**		**138**	**107**		**107**
No of contexts/units	**1**	**1**		**2**	**2**		**9**	**9**		**6**		**6**	**1**		**1**	**1**		**1**

Table 5.13b: Per phase summary fragment counts analysed by Kabukcu (CK), Asouti (EA) and combined summary fragment counts from all sites. (Fragment counts from primary fire features and in situ burning deposits studied in the present thesis (CK) and Asouti 2002, 2003, 2005, 2013 (EA)) (*continued overleaf*)

Site/Phase	**Ch. South P**			**Ch. South Q**			**Ch. South R**			**Ch. South S**			**Ch. TP**			**Ch. West**		
	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA	Total Frgmt C.	CK	EA
Juniperus	258	88	170	144	50	94	36	36								24	24	
Quercus	580	366	214	154	56	98	5	5		25	25					2	2	
Amygdalus	15	4	11				1	1								2	2	
Pistacia	13	9	4	3		3										2	2	
Prunus	2	2														1	1	
Maloideae																		
Salicaceae	101	60	41	7		7							21		21	1	1	
Ulmaceae	131	96	35				5	5					49		49	12	12	
Ulmus	25	19	6	12		12	3	3					18		18			
Celtis	20	16	4	2		2	2	2					3		3			
Fraxinus	16	6	10	94	45	49	10	10								2	2	
Tamarix	1	1														2	2	
Artemisia	22	20	2				1	1										
Chenopodiaceae	2	2		1		1												
Leguminoseae	3	3											1		1	1	1	
Capparis	5	1	4													2	2	
Labiatae	2		2															
Total Identified	**1196**	**693**	**503**	**417**	**151**	**266**	**63**	**63**		**25**	**25**		**92**		**92**	**51**	**51**	
No of contexts/units	**32**	**24**	**8**	**12**	**8**	**4**	**6**	**6**		**1**	**1**		**1**		**1**	**4**	**4**	

(*continued from previous page*) **Table 5.13b:** Per phase summary fragment counts analysed by Kabukcu (CK), Asouti (EA) and combined summary fragment counts from all sites. (Fragment counts from primary fire features and in situ burning deposits studied in the present thesis (CK) and Asouti 2002, 2003, 2005, 2013 (EA)).

Phase	**South G (N=2)**		**South G-H (N=2)**		**South K (N=3)**		**South L (N=3)**		**South M (N=1)**		**South O (N=2)**		**South P (N=4)**		**South Q (N=4)**		**South R (N=6)**		**South S (N=3)**		**South T (N=5)**		**TP (N=4)**	
	C	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**	**C**	**%C**
Juniperus	3	3.53	1	0.52	8	3.28	5	2.54	1	2.04	36	20.81	5	1.47	60	26.91	116	41.43	39	36.79	91	52.91	38	18.36
Quercus	9	10.59	49	25.52	59	24.18	82	41.62	23	46.94	78	45.09	144	42.35	62	27.80	53	18.93	20	18.87	28	16.28	31	14.98
Amygdalus	2	2.35	4	2.08							10	5.78	3	0.88	8	3.59	23	8.21	8	7.55	12	6.98	12	5.80
Pistacia	6	7.06			13	5.33					2	1.16	3	0.88	10	4.48	7	2.50	12	11.32	13	7.56	1	0.48
Prunus			2	1.04			1	0.51					2	0.59										
Maloideae	1	1.18	6	3.13	6	2.46	3	1.52			1	0.58	6	1.76									1	0.48
Anacardiaceae			1	0.52	1	0.41	1	0.51			4	2.31												
Rhamnus			3	1.56																				
Ulmaceae	10	11.76	31	16.15	32	13.11	2	1.02			7	4.05	52	15.29	24	10.76	25	8.93	4	3.77	13	7.56	31	14.98
Ulmus	9	10.59	24	12.50	19	7.79	33	16.75	23	46.94	16	9.25	22	6.47	11	4.93	4	1.43		0.00	1	0.58	31	14.98
Celtis	25	29.41	19	9.90	34	13.93	25	12.69			1	0.58	14	4.12	5	2.24	7	2.50	1	0.94			29	14.01
Salicaceae	18	21.18	39	20.31	41	16.80	21	10.66	1	2.04	15	8.67	77	22.65	20	8.97	3	1.07			5	2.91	17	8.21
Fraxinus					3	1.23	19	9.64							20	8.97	41	14.64	21	19.81	9	5.23	8	3.86
Acer					1	0.41											1	0.36						
Chenopodiaceae			6	3.13	2	0.82	3	1.52																
Artemisia	1	1.18	5	2.60	7	2.87							6	1.76	2	0.90			1	0.94			5	2.42
Leguminosae	1	1.18	2	1.04	12	4.92	1	0.51			2	1.16	1	0.29									3	1.45
Capparis					3	1.23	1	0.51	1	2.04			2	0.59										
Tamarix					1	0.41					1	0.58	3	0.88	1	0.45								
Labiatae					1	0.41																		
Rosaceae					1	0.41																		
Total Identified	**85**	**100.0**	**192**	**100.0**	**244**	**100.0**	**197**	**100.0**	**49**	**100.0**	**173**	**100.0**	**340**	**100.0**	**223**	**100.0**	**280**	**100.0**	**106**	**100.0**	**172**	**100.0**	**207**	**100.0**

Table 5.14: Summary fragment counts (C) and percentage fragment counts (% C) for all taxa found in samples from Çatalhöyük East dispersed contexts analysed in the present study.

Çatalhöyük West mound dispersed contexts				
	Fragment count	**Ubiquity**	**% C**	**% U**
Juniperus	198	12	42.31	100
Quercus	45	7	9.62	58.33
Amygdalus	13	6	2.78	50
Pistacia	9	5	1.92	41.67
Maloideae	1	1	0.21	8.33
Prunus	1	1	0.21	8.33
Salicaceae	14	6	2.99	50
Ulmaceae	129	12	27.56	100
Ulmus	14	8	2.99	66.67
Celtis	14	4	2.99	33.33
Fraxinus	13	6	2.78	50
Acer	1	1	0.21	8.33
Tamarix	1	1	0.21	8.33
Artemisia	7	2	1.50	16.67
Chenopodiaceae	3	3	0.64	25
Leguminosae	5	4	1.07	33.33
Total Identified	**468**	**(N=12)**	**100.00**	

Table 5.15: Summary fragment counts, ubiquity (sample presence), percentage fragment counts (% C) and ubiquity scores (% U) for all taxa found in Çatalhöyük West mound dispersed contexts.

	South G		**South G-H**		**South I**		**South J**		**South K**		**South L**		**South M**		**South O**		**South P**		**South Q**		**South R**		**South S**		**South T**		**TP**	
	U	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U %**	**U**	**U%**
Juniperus	5	28	5	38	1	17	2	100	6	67	8	73	4	100	2	100	5	71	6	100	6	100	7	100	5	100	7	78
Quercus	11	61	13	100	6	100	2	100	9	100	11	100	4	100	2	100	7	100	6	100	6	100	5	71	5	100	8	89
Amygdalus	10	56	2	15	1	17	1	50	3	33			1	25	2	100	2	29	4	67	6	100	6	86	4	80	7	78
Pistacia	12	67	8	62	1	17	1	50	9	100			3	75	1	50	4	57	2	33	2	33	5	71	4	80	6	67
Prunus			2	15					1	11	1	9	2	50			2	29										
Maloideae	7	39	8	62	1	17	1	50	7	78	2	18	2	50	1	50	3	43									1	11
Anacardiaceae			1	8					1	11	1	9			2	100												
Rhamnus			1	8																								
Salicaceae	14	78	13	100	6	100	2	100	9	100	11	100	4	100	2	100	6	86	5	83	2	33	2	29	1	20	9	100
Ulmaceae	18	100	12	92	6	100	2	100	9	100	10	91	2	50	2	100	7	100	6	100	6	100	4	57	2	40	9	100
Ulmus	13	72	5	38	3	50	2	100	8	89	11	100	4	100	2	100	4	57	4	67	2	33	2	29	1	20	8	89
Celtis	15	83	12	92	3	50	1	50	9	100	9	82	2	50	1	50	5	71	2	33	4	67	1	14			7	78
Fraxinus			1	8	1	17	1	50	4	44	5	45	1	25			1	14	5	83	6	100	7	100	3	60	8	89
Acer									2	22	1	9	2	50							1	17	2	29				
Tamarix	3	17							1	11	1	9	2	50	1	50	3	43	1	17							1	11
Chenopodiaceae			4	31	2	33			3	33	7	64	3	75														
Artemisia	5	28	6	46					5	56	6	55	2	50			2	29	1	17			1	14			2	22
Leguminosae	1	6	4	31					7	78	8	73	1	25	1	50	1	14									2	22
Labiatae	4	22			1	17	1	50	5	56	1	9	1	25														
Rosaceae	1	6							1	11	1	9	1	25														
Capparis			1	8					3	33	1	9	1	25			1	14										
Caprifoliaceae	2	11											1	25														
Alnus											1	9	1	25														
Vitex	2	11	1								1	9	1	25														
Platanus											1	9																
Ficus carica	1	6									1	9					1	14										
Ephedra	1	6																										
Total N	**18**		**13**		**6**		**2**		**9**		**11**		**4**		**2**		**7**		**6**		**6**		**7**		**5**		**9**	

Table 5.16: Number of contexts in which each taxon was present (U) and ubiquity scores (U %) for all taxa found in Çatalhöyük dispersed contexts (middens), grouped by phase (including data published in Asouti 2005, 2013).

Site/Phase	**PB Epipal. (N=13)**		**PB Acer. NL NL (N=25)**		**PB Late NL (N=28)**		**PB Chalco. (N=8)**		**Can Hasan III (N=23)**		**BK Trench K (N=11**		**BK Trench H (N=23)**		**BK Trench N (N=10)**		**BK Trench M (N=23)**	
	C	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**
Pinus cf. *nigra*									8	1.22							1	0.40
Juniperus	53	28.96	1	0.27	3	0.07			21	3.21	3	3.30			2	0.73	5	1.98
Quercus			3	0.82	1	0.02	1	0.09	17	2.60	2	2.20	8	2.61	21	7.64	13	5.16
Amygdalus	95	51.91	346	94.54	2858	64.21	683	63.71	187	28.55	15	16.48	36	11.73	26	9.45	8	3.17
Pistacia	7	3.83	3	0.82	1355	30.44	327	30.50	109	16.64	28	30.77	2	0.65	4	1.45	2	0.79
Anacardiaceae															1	0.36		
Prunus			3	0.82			1	0.09					1	0.33	5	1.82		
Maloideae	21	11.48					15	1.40	7	1.07								
Ulmaceae	1	0.55							227	34.66			1	0.33	5	1.82		
Ulmus									12	1.83								
Celtis	2	1.09			104	2.34	12	1.12	2	0.31								
Salicaceae	1	0.55							33	5.04	38	41.76	225	73.29	145	52.73	201	79.76
Fraxinus	3	1.64			24	0.54	2	0.19					7	2.28	2	0.73		
Acer					1	0.02												
Tamarix					36	0.81	4	0.37							26	9.45	11	4.37
Platanus																		
Alnus																		
Vitex																		
Labiatae																		
Rhamnus					1	0.02	20	1.87										
Artemisia			3	0.82	5	0.11	3	0.28			4	4.40	1	0.33	1	0.36	1	0.40
Chenopodiaceae			1	0.27					2	0.31	1	1.10	2	0.65			1	0.40
Leguminosae			1	0.27	4	0.09			7	1.07			7	2.28	29	10.55	4	1.59
Capparis					3	0.07			2	0.31			5	1.63			1	0.40
Ephedra													1	0.33				
Caprifoliaceae																		
Ficus carica																		
Clematis					7	0.16	1	0.09										
Rosaceae			5	1.37	49	1.10	3	0.28										
cf. *Arbutus*													1	0.33				
cf. *Paliurus/Ziziphus*													3	0.98	4	1.45	1	0.40
cf. Euphorbiaceae													6	1.95	4	1.45	3	1.19
cf. Maloideae													1	0.33				
Ulmaceae/Anacardiaceae									21	3.21								
Total Identified	**183**	**100.0**	**366**	**100.0**	**4451**	**100.0**	**1072**	**100.0**	**655**	**100.0**	**91**	**100.0**	**307**	**100.0**	**275**	**100.0**	**252**	**100.0**

Table 5.17: Master anthracological sequence (C: frg. counts; % C: percentage frg. counts) from all Konya Plain sites (incorporating data from Asouti 2003, 2005, 2013) *(continued overleaf)*

Site/Phase	Ch. South G (N=18)		Ch. South G-H (N=13)		Ch. South I (N=6)		Ch. South J (N=2)		Ch. South K (N=9)		Ch. South L (N=11)		Ch. South M (N=4)	
	C	% C	C	% C	C	% C	C	% C	C	% C	C	% C	C	% C
Pinus cf. *nigra*														
Juniperus	9	0.80	7	0.56	1	0.16	2	0.94	23	2.51	28	2.40	20	5.00
Quercus	31	2.75	651	52.46	384	61.44	130	61.03	371	40.46	636	54.55	253	63.25
Amygdalus	21	1.87	4	0.32	1	0.16	1	0.47	7	0.76	8	0.69	1	0.25
Pistacia	39	3.46	19	1.53	1	0.16	1	0.47	26	2.84	19	1.63	14	3.50
Anacardiaceae			1	0.08					1	0.11	1	0.09		
Prunus	1	0.09	2	0.16							8	0.69	2	0.50
Maloideae	16	1.42	19	1.53	1	0.16	7	3.29	68	7.42	19	1.63	4	1.00
Ulmaceae	473	42.01	119	9.59	88	14.08	26	12.21	110	12.00	61	5.23	5	1.25
Ulmus	86	7.64	28	2.26	7	1.12	2	0.94	37	4.03	70	6.00	38	9.50
Celtis	132	11.72	126	10.15	12	1.92	3	1.41	67	7.31	69	5.92	11	2.75
Salicaceae	281	24.96	226	18.21	126	20.16	28	13.15	127	13.85	146	12.52	31	7.75
Fraxinus			1	0.08	1	0.16	12	5.63	7	0.76	24	2.06	2	0.50
Acer									2	0.22	5	0.43	2	0.50
Tamarix	3	0.27							1	0.11	1	0.09	3	0.75
Platanus											1	0.09		
Alnus											1	0.09	2	0.50
Vitex	2	0.18	2	0.16							4	0.34	1	0.25
Labiatae	5	0.44			1	0.16	1	0.47	6	0.65	5	0.43	1	0.25
Rhamnus			3	0.24										
Artemisia	14	1.24	15	1.21					11	1.20	8	0.69	2	0.50
Chenopodiaceae	7	0.62	9	0.73	2	0.32			10	1.09	18	1.54	3	0.75
Leguminosae	1	0.09	8	0.64					38	4.14	31	2.66	2	0.50
Capparis			1	0.08					4	0.44	1	0.09	1	0.25
Ephedra	1	0.09												
Caprifoliaceae	1	0.09											1	0.25
Ficus carica											1	0.09		
Clematis														
Rosaceae	3	0.27							1	0.11	1	0.09	1	0.25
cf. *Arbutus*														
cf. *Paliurus*/*Ziziphus*														
cf. Euphorbiaceae														
cf. Maloideae														
Ulmaceae/Anacardiaceae														
Total Identified	**1126**	**100.0**	**1241**	**100.0**	**625**	**100.0**	**213**	**100.0**	**917**	**100.0**	**1166**	**100.0**	**400**	**100.0**

(continued from previous page) **Table 5.17:** Master anthracological sequence (C: frg. counts; % C: percentage frg. counts) from all Konya Plain sites (incorporating data from Asouti 2003, 2005, 2013) *(continued overleaf)*

Site/Phase	Ch. South O (N=2)		Ch. South P (N=7)		Ch. South Q (N=6)		Ch. South R (N=6)		Ch. South S (N=7)		Ch. South T (N=5)		Ch. TP (N=9)		Ch. West (N=12)	
	C	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**	**C**	**% C**
Pinus cf. *nigra*																
Juniperus	36	20.81	42	7.14	104	34.90	116	41.43	294	67.28	91	52.91	108	18.78	198	42.31
Quercus	78	45.09	270	45.92	83	27.85	53	18.93	48	10.98	28	16.28	45	7.83	45	9.62
Amygdalus	10	5.78	8	1.36	11	3.69	23	8.21	35	8.01	12	6.98	22	3.83	13	2.78
Pistacia	2	1.16	6	1.02	10	3.36	7	2.50	15	3.43	13	7.56	23	4.00	9	1.92
Anacardiaceae	4	2.31														
Prunus			2	0.34											1	0.21
Maloideae	1	0.58	6	1.02									1	0.17	1	0.21
Ulmaceae	7	4.05	96	16.33	27	9.06	25	8.93	7	1.60	13	7.56	173	30.09	129	27.56
Ulmus	16	9.25	22	3.74	11	3.69	4	1.43	4	0.92	1	0.58	76	13.22	14	2.99
Celtis	1	0.58	17	2.89	5	1.68	7	2.50	1	0.23			39	6.78	14	2.99
Salicaceae	15	8.67	102	17.35	21	7.05	3	1.07	2	0.46	5	2.91	58	10.09	14	2.99
Fraxinus			3	0.51	23	7.72	41	14.64	28	6.41	9	5.23	18	3.13	13	2.78
Acer							1	0.36	2	0.46					1	0.21
Tamarix	1	0.58	4	0.68	1	0.34							3	0.52	1	0.21
Platanus																
Alnus																
Vitex																
Labiatae																
Rhamnus																
Artemisia			6	1.02	2	0.67			1	0.23			5	0.87	7	1.50
Chenopodiaceae															3	0.64
Leguminosae	2	1.16	1	0.17									4	0.70	5	1.07
Capparis			2	0.34												
Ephedra																
Caprifoliaceae																
Ficus carica			1	0.17												
Clematis																
Rosaceae																
cf. *Arbutus*																
cf. *Paliurus*/*Ziziphus*																
cf. Euphorbiaceae																
cf. Maloideae																
Ulmaceae/Anacardiaceae																
Total Identified	**173**	**100.0**	**588**	**100.0**	**298**	**100.0**	**280**	**100.0**	**437**	**100.0**	**172**	**100.0**	**575**	**100.0**	**468**	**100.0**

(continued from previous page) **Table 5.17:** Master anthracological sequence (C: frg. counts; % C: percentage frg. counts) from all Konya Plain sites (incorporating data from Asouti 2003, 2005, 2013).

Dendrological features		Dispersed contexts		Fire features	
		Count	**%**	**Count**	**%**
Curvature degree (Marguerie and Hunot 2007)	1	137	4.9%	13	1.3%
	2	850	30.7%	319	32.1%
	3	733	26.5%	225	22.6%
	N/A	1048	37.9%	437	44.0%
Pith		195	7.0%	125	12.6%
Bark		41	1.5%	59	5.9%
Tyloses		1802	65.1%	620	62.4%
Resin canals/gum ducts		599	21.6%	144	14.5%
Fungal hyphae		1335	48.2%	610	61.4%
Narrow growth rings		424	15.3%	177	17.8%
Radial cracks		145	5.2%	22	2.2%
Collapsed vessels		180	6.5%	37	3.7%
Boreholes		44	1.6%	2	0.2%
Scar/callus tissue		30	1.1%	1	0.1%
Mineral deposits		166	6.0%	75	7.5%
Reaction wood		44	1.6%	9	0.9%
False rings		45	1.6%	10	1.0%
Knots		193	7.0%	60	6.0%
Total number of analysed wood charcoal fragments		**2768**		**994**	

Table 5.18: Summary of dendrological observations (numbers of fragments exhibiting individual features) obtained from wood charcoal fragments from dispersed contexts and fire features at Çatalhöyük East and West mounds.

		Dispersed contexts												
Dendrological features		**South G**	**South G-H**	**South K**	**South L**	**South M**	**South O**	**South P**	**South Q**	**South R**	**South S**	**South T**	**TP**	**West**
Curvature degree (Marguerie and Hunot 2007)	1	1	5	22	56	10	18	7	12		6			
	2	28	55	70	74	17	64	72	78	96	28	37	162	150
	3	22	83	102	52	15	33	124	45	47	69	33	80	74
	N/A	34	54	56	17	7	60	145	88	137	49	102	49	250
Pith		2	41	26	14	4	10	42	9	3	1	2	27	14
Bark			10	5	4			9	2	1		1	7	2
Tyloses		77	107	229	169	43	134	278	144	139	64	74	144	200
Resin canals/gum ducts		14	13	48	36	6	48	103	40	76	21	32	38	124
Fungal hyphae		34	104	151	98	29	104	197	116	99	43	46	91	223
Narrow growth rings		3	12	15	29	9	22	32	44	72	45	46	44	51
Radial cracks		2	20	24	27	3	2	25	15	6	3	4	10	4
Collapsed vessels		12	30	19	22	6	3	43	13	5	1	2	7	17
Boreholes			2	1	1	1		11	2	8	1	1		16
Scar/callus tissue			1	2	6	1	3	12	1	1			2	1
Mineral deposits		1	4	3	1		4	14	13	29	11	24	33	29
Reaction wood		3	1		3	1	1	5	5	7	3	2	4	9
False rings				1	6	1	2	5	10	11	1	4		4
Knots		17	11	31	24	2	5	28	15	16	3	6	14	21
Total number of analysed wood charcoal fragments		**85**	**197**	**250**	**199**	**49**	**175**	**348**	**223**	**280**	**152**	**172**	**291**	**474**

Table 5.19: Summary of dendrological observations (numbers of fragments exhibiting individual dendrological features) obtained from wood charcoal fragments from dispersed contexts at Çatalhöyük East and West mounds, grouped by phase.

		Fire features				
Dendrological features		**South P**	**South Q**	**South R**	**South S**	**West**
Curvature degree (Marguerie and Hunot 2007)	1	13				
	2	233	47	12	6	21
	3	191	15	11		8
	N/A	254	102	40	19	22
Pith		120		2		3
Bark		56				3
Tyloses		445	110	22	25	18
Resin canals/gum ducts		85	25	20		14
Fungal hyphae		450	91	23	18	28
Narrow growth rings		121	29	16	6	5
Radial cracks		18	3			1
Collapsed vessels		36	1			
Bore holes		2				
Scar/callus tissue		1				
Mineral deposits		56	7	10		2
Reaction wood		6	1	2		
False rings		9		1		
Knots		45	11	4		
Total number of analysed wood charcoal fragments		**691**	**164**	**63**	**25**	**51**

Table 5.20: Summary of dendrological observations (numbers of fragments exhibiting individual dendrological features) obtained from wood charcoal fragments from fire features at Çatalhöyük East and West mounds, grouped by phase.

Goodness-of-fit statistics			
	Weibull	**gamma**	**lognormal**
Kolmogorov-Smirnov	0.1320358	0.154853	**0.09109262**
Cramer-von Mises	0.8513320	1.115901	**0.35236897**
Anderson-Darling	4.8971829	5.843586	**1.84089556**
Goodness-of-fit criteria			
	Weibull	**gamma**	**lognormal**
Aikake's Information Cri.	1824.490	1826.066	**1785.621**
Bayesian Information Cri.	1830.898	1832.474	**1792.029**

Table 5.21: Goodness-of-fit statistics and criteria values comparing Weibull, gamma and lognormal distribution for diameter measurements from the Çatalhöyük anthracological assemblage. As indicated by the lowest values, the best fit is confirmed as lognormal. Calculations were carried out using R 3.1.2 (package ‘fitdistrplus’).

	eigenvalue	% of variance	Cumulative % of variance
Dim. 1	0.817532	31.21	31.21
Dim. 2	0.46493	17.75	48.96
Dim. 3	0.293986	11.22	60.19
Dim. 4	0.21422	8.18	68.37
Dim. 5	0.176997	6.76	75.12
Dim. 6	0.153611	5.86	80.99
Dim. 7	0.110744	4.23	85.22
Dim. 8	0.099483	3.8	89.01
Dim. 9	0.088909	3.39	92.41
Dim. 10	0.080095	3.06	95.47
Dim. 11	0.061016	2.33	97.8
Dim. 12	0.036318	1.39	99.18
Dim. 13	0.021388	0.82	100

Table 5.22a: Results of CA run on per sample wood charcoal taxon counts from all sites included in the present study: eigenvalues and percentage of variance for dimensions.

	Contribution to dimensions				
	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5
Juniperus	3.41	**79.76**	0.24	2.22	0.00
Quercus	**20.55**	5.87	**42.25**	3.99	3.12
Amygdalus	**41.77**	0.05	0.40	0.01	0.01
Pistacia	**16.45**	0.13	0.01	0.40	0.01
Prunus	0.10	0.09	0.01	0.44	0.17
Maloideae	0.45	0.21	0.22	0.15	**34.76**
Ulmaceae	5.29	0.01	**41.93**	**22.31**	0.04
Ulmus	2.25	0.01	3.12	4.87	0.02
Celtis	0.85	0.75	0.77	0.41	0.17
Salicaceae	7.70	7.55	9.34	**46.42**	1.43
Fraxinus	0.35	5.06	0.48	0.33	0.00
Tamarix	0.10	0.10	0.66	**15.09**	3.46
Artemisia	0.23	0.05	0.40	0.06	0.09
Leguminosae	0.51	0.36	0.18	3.29	**56.70**

Table 5.22b: Results of CA run on per sample wood charcoal taxon counts from all sites included in the present study: contribution of variables to dimensions.

	eigenvalue	% of variance	Cumulative % of variance
Dim 1	0.492144	33.58	33.58
Dim 2	0.292042	19.92	53.50
Dim 3	0.141277	9.64	63.14
Dim 4	0.103133	7.04	70.17
Dim 5	0.096544	6.59	76.76
Dim 6	0.092821	6.33	83.09
Dim 7	0.06159	4.20	87.30
Dim 8	0.05007	3.42	90.71
Dim 9	0.043331	2.96	93.67
Dim 10	0.036942	2.52	96.19
Dim 11	0.027924	1.91	98.09
Dim 12	0.014987	1.02	99.12
Dim 13	0.012955	0.88	100.00

Table 5.23a: Results of CA run on Çatalhöyük per sample (dispersed contexts) wood charcoal taxon counts: eigenvalues and percentage of variance.

	Contribution to dimensions				
	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5
Juniperus	**71.82**	1.25	0.35	4.29	2.43
Quercus	**10.07**	**40.67**	5.07	0.98	5.19
Amygdalus	3.35	0.15	0.05	0.22	0.95
Pistacia	0.07	0.96	0.02	0.07	5.39
Prunus	0.08	0.03	0.22	0.05	0.09
Maloideae	1.11	0.08	**68.41**	0.42	2.81
Ulmaceae	0.25	**44.85**	2.49	1.34	**21.58**
Ulmus	0.15	4.52	0.01	**40.46**	1.94
Celtis	1.38	2.28	1.63	2.63	**18.21**
Salicaceae	4.97	3.12	0.15	**27.55**	**13.11**
Fraxinus	6.31	0.84	0.01	**21.33**	**27.48**
Tamarix	0.00	0.22	0.00	0.01	0.07
Artemisia	0.10	0.70	0.34	0.65	0.53
Leguminosae	0.35	0.33	**21.23**	0.00	0.21

Table 5.23b: Results of CA run on Çatalhöyük per sample (dispersed contexts) wood charcoal taxon counts: contribution of variables to dimensions.

	eigenvalue	% of variance	Cumulative % of variance
Dim. 1	0.60	32.05	32.05
Dim. 2	0.44	23.62	55.67
Dim. 3	0.23	12.03	67.70
Dim. 4	0.15	8.13	75.83
Dim. 5	0.10	5.21	81.05
Dim. 6	0.08	4.35	85.40
Dim. 7	0.07	3.98	89.38
Dim. 8	0.06	3.42	92.80
Dim. 9	0.04	2.28	95.08
Dim. 10	0.03	1.71	96.79
Dim. 11	0.03	1.36	98.15
Dim. 12	0.02	1.11	99.26
Dim. 13	0.01	0.74	100.00

Table 5.24a: Results of CA run on Çatalhöyük per sample (primary fuel waste contexts) wood charcoal taxon counts: eigenvalues and percentage of variance.

	Contribution to dimensions				
	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5
Juniperus	**43.78**	2.46	**29.92**	0.12	0.65
Quercus	2.60	**55.94**	0.83	0.05	0.07
Amygdalus	0.23	0.99	2.28	5.34	**16.53**
Pistacia	0.14	0.17	0.00	2.10	6.52
Prunus	0.07	0.20	0.13	0.31	2.38
Maloideae	0.58	0.52	0.00	**10.10**	**41.16**
Ulmaceae	**10.57**	**17.94**	0.04	**12.06**	0.03
Ulmus	2.46	2.29	0.00	**32.16**	1.45
Celtis	1.70	3.02	0.01	11.22	5.75
Salicaceae	**12.79**	**11.07**	0.25	**18.61**	0.01
Fraxinus	**23.98**	3.79	**66.18**	0.01	0.05
Tamarix	0.04	0.19	0.11	0.21	0.33
Artemisia	0.92	1.37	0.25	7.51	0.69
Leguminosae	0.14	0.06	0.00	0.19	**24.39**

Table 5.24b: Results of CA run on Çatalhöyük per sample (primary fuel waste contexts) wood charcoal taxon counts: contribution of variables to dimensions.

	eigenvalue	% of variance	cumulative % of variance
Dim 1	0.15	13.85	13.85
Dim 2	0.11	10.46	24.31
Dim 3	0.08	7.41	31.72
Dim 4	0.08	7.24	38.96
Dim 5	0.07	6.81	45.77
Dim 6	0.07	6.53	52.30
Dim 7	0.07	6.35	58.65
Dim 8	0.06	6.08	64.72
Dim 9	0.06	5.81	70.54
Dim 10	0.06	5.44	75.98
Dim 11	0.06	5.18	81.16
Dim 12	0.05	4.78	85.94
Dim 13	0.05	4.27	90.21
Dim 14	0.04	3.99	94.20
Dim 15	0.03	3.13	97.33
Dim 16	0.03	2.67	100.00

Table 5.25a: Results of MCA run on dendrological features recorded for Çatalhöyük wood charcoal specimens: eigenvalues and percentage of variance.

	Contribution to dimensions					**$\cos^2$**				
	Dim 1	**Dim 2**	**Dim 3**	**Dim 4**	**Dim 5**	**Dim 1**	**Dim 2**	**Dim 3**	**Dim 4**	**Dim 5**
CD1	3.37	0.38	2.50	**11.66**	**17.51**	0.0799	0.0068	0.0318	0.1445	0.2042
CD2	4.84	4.95	1.09	0.13	2.15	0.2208	0.1708	0.0267	0.0031	0.0483
CD3	**10.00**	4.93	0.28	0.91	0.00	0.3819	0.1422	0.0057	0.0182	0.0000
Pith_0	3.39	0.95	0.01	0.32	0.04	0.5454	0.1158	0.0007	0.0270	0.0032
Pith_1	**21.21**	**5.96**	0.05	2.01	0.25	0.5454	0.1158	0.0007	0.0270	0.0032
Bark_0	0.75	0.14	0.01	0.25	0.02	0.3788	0.0534	0.0039	0.0650	0.0061
Bark_1	**16.34**	3.05	0.32	**5.37**	0.54	0.3788	0.0534	0.0039	0.0650	0.0061
Tyloses_0	**13.72**	**5.88**	0.07	0.60	0.84	0.4718	0.1527	0.0014	0.0108	0.0142
Tyloses_1	**7.57**	3.24	0.04	0.33	0.46	0.4718	0.1527	0.0014	0.0108	0.0142
Knots_0	0.01	0.02	0.07	1.74	0.03	0.0037	0.0065	0.0183	0.4445	0.0078
Knots_1	0.16	0.37	1.47	**36.67**	0.69	0.0037	0.0065	0.0183	0.4445	0.0078
Trauma canal_0	0.16	**5.47**	1.91	0.00	0.03	0.0175	0.4452	0.1105	0.0002	0.0017
Trauma canal_1	0.63	**21.14**	7.40	0.01	0.12	0.0175	0.4452	0.1105	0.0002	0.0017
Scar tissue_0	0.00	0.00	0.07	0.06	0.06	0.0003	0.0089	0.1099	0.0875	0.0889
Scar tissue_1	0.01	0.53	**9.20**	**7.50**	**8.10**	0.0003	0.0089	0.1099	0.0875	0.0889
Narrow gr. ring_0	0.19	3.32	2.03	1.36	0.57	0.0215	0.2792	0.1205	0.0790	0.0312
Narrow gr. ring_1	0.78	**13.36**	**8.14**	**5.47**	2.29	0.0215	0.2792	0.1205	0.0790	0.0312
Reaction wood_0	0.01	0.07	0.04	0.08	0.03	0.0144	0.0806	0.0343	0.0669	0.0248
Reaction wood_1	0.64	4.75	2.85	**5.69**	2.24	0.0144	0.0806	0.0343	0.0669	0.0248
False rings_0	0.02	0.11	0.00	0.12	0.03	0.0169	0.0901	0.0000	0.0684	0.0162
False rings_1	0.75	**5.27**	0.00	**5.79**	1.45	0.0169	0.0901	0.0000	0.0684	0.0162
Boreholes_0	0.00	0.02	0.26	0.04	0.17	0.0000	0.0236	0.2247	0.0322	0.1383
Boreholes_1	0.00	1.39	**18.69**	2.75	**12.52**	0.0000	0.0236	0.2247	0.0322	0.1383
Radial cracks_0	0.01	0.16	0.66	0.01	0.83	0.0027	0.0449	0.1282	0.0027	0.1489
Radial cracks_1	0.11	2.52	**10.15**	0.22	**12.83**	0.0027	0.0449	0.1282	0.0027	0.1489
Mineral deposits_0	0.02	0.14	0.65	0.03	0.98	0.0071	0.0396	0.1264	0.0049	0.1742
Mineral deposits_1	0.30	2.22	**10.01**	0.40	**15.02**	0.0071	0.0396	0.1264	0.0049	0.1742
Collapsed vessels_0	0.01	0.05	1.14	0.36	1.08	0.0048	0.0148	0.2455	0.0757	0.2151
Collapsed vessels_1	0.20	0.84	**19.57**	**6.18**	**18.66**	0.0048	0.0148	0.2455	0.0757	0.2151
Fungal hyphae_0	**7.73**	4.57	0.67	2.06	0.22	0.3281	0.1464	0.0153	0.0457	0.0045
Fungal hyphae_1	**7.07**	4.18	0.62	1.88	0.20	0.3281	0.1464	0.0153	0.0457	0.0045

Table 5.25b: Results of MCA run on dendrological features recorded for Çatalhöyük wood charcoal specimens: contribution of variables to dimensions, and $\cos^2$ values.

	eigenvalue	% of variance	cumulative % of variance
comp 1	1.724	47.03	47.03
comp 2	0.649	17.70	64.72
comp 3	0.430	11.74	76.46
comp 4	0.287	7.82	84.28
comp 5	0.134	3.65	87.93
comp 6	0.096	2.61	90.54
comp 7	0.076	2.07	92.61
comp 8	0.058	1.58	94.19
comp 9	0.040	1.08	95.26
comp 10	0.036	0.98	96.24
comp 11	0.028	0.77	97.01
comp 12	0.020	0.54	97.55
comp 13	0.018	0.50	98.05
comp 14	0.016	0.44	98.50
comp 15	0.013	0.36	98.85
comp 16	0.010	0.28	99.14
comp 17	0.007	0.20	99.34
comp 18	0.006	0.16	99.49
comp 19	0.004	0.12	99.61
comp 20	0.003	0.08	99.70
comp 21	0.002	0.07	99.76
comp 22	0.002	0.06	99.82
comp 23	0.002	0.04	99.87
comp 24	0.001	0.04	99.90
comp 25	0.001	0.03	99.94
comp 26	0.001	0.03	99.96
comp 27	0.000	0.01	99.98
comp 28	0.000	0.01	99.99
comp 29	0.000	0.01	99.99
comp 30	0.000	0.00	100.00

Table 5.26a: Results of MFA run on Çatalhöyük per sample (dispersed and primary fuel waste contexts) wood charcoal taxon and dendrological counts: eigenvalues and percentage of variance.

	Contribution to dimensions				
	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Dendro	50.83	38.97	30.85	31.44	31.52
Taxa	49.17	61.03	69.15	68.56	68.48

Table 5.26b: Results of MFA run on Çatalhöyük per sample (dispersed and primary fuel waste contexts) wood charcoal taxon and dendrological counts: contribution of groups to dimensions.

		Contribution to dimensions				
		Dim.1	**Dim.2**	**Dim.3**	**Dim.4**	**Dim.5**
Dendroecological features	Pith	3.48	**11.40**	0.84	5.02	**10.23**
	Bark	0.31	1.60	0.45	1.62	2.30
	Tyloses	**19.28**	1.79	8.18	**20.77**	0.46
	Traumatic canals	0.47	0.15	9.58	0.34	1.85
	Fungal hyphae	**12.35**	0.01	1.99	0.53	0.03
	Narrow gr. rings	0.01	0.14	1.04	0.04	9.11
	Radial cracks	0.45	0.00	0.14	0.73	0.10
	Collapsed vessels	0.52	0.18	0.00	0.02	0.00
	Boreholes	0.00	0.00	0.04	0.02	0.07
	Scar callus tissue	0.01	0.00	0.02	0.00	0.00
	Mineral deposits	0.01	0.92	0.04	0.00	0.98
	Reaction wood	0.00	0.01	0.01	0.00	0.01
	False rings	0.00	0.04	0.06	0.02	0.36
	Knots	0.21	0.01	0.04	0.90	0.14
	CD1	0.61	1.06	1.94	1.34	3.07
	CD2	1.42	0.08	6.49	0.08	0.08
	CD3	**11.68**	**21.58**	0.00	0.02	2.73
Wood charcoal taxa	*Juniperus*	**15.16**	9.52	**60.34**	2.09	0.98
	Quercus	**20.61**	**17.26**	4.75	**45.16**	0.00
	Amygdalus	0.02	0.07	0.29	0.06	0.03
	Pistacia	0.00	0.01	0.25	0.18	0.88
	Prunus	0.01	0.01	0.00	0.00	0.00
	Maloideae	0.08	0.00	0.01	0.07	0.27
	Salicaceae	7.19	1.49	0.03	0.26	**27.64**
	Ulmaceae	2.36	**31.02**	1.83	3.46	2.09
	Ulmus	2.38	0.05	0.43	4.41	0.17
	Celtis	0.80	0.22	0.16	**10.49**	2.29
	Fraxinus	0.31	0.09	0.91	2.11	**33.95**
	Tamarix	0.00	0.00	0.00	0.00	0.00
	Artemisia	0.18	1.25	0.13	0.00	0.16
	Leguminosae	0.05	0.02	0.01	0.26	0.01

Table 5.26c: Results of MFA run on Çatalhöyük per sample (dispersed and primary fuel waste contexts) wood charcoal taxon and dendrological counts: contribution of variables to dimensions.

Dim.1 main components			Dim.2 main components		
	correlation	**p value**		**correlation**	**p value**
Fungal hyphae	0.9162	0	Ulmaceae	0.8208	0
Tyloses	0.8606	0	Pith	0.6433	0
Salicaceae	0.7691	0	CD3	0.6179	0
Collapsed vessels	0.7632	0	*Artemisia*	0.6012	0
Quercus	0.7576	0	Mineral deposits	0.554	0
CD3	0.7412	0	Bark	0.5361	0
Radial cracks	0.6616	0	*Juniperus*	0.3228	0.0143
Ulmus	0.6426	0	False rings	0.3008	0.023
Maloideae	0.6199	0	Reaction wood	0.2822	0.0335
Knots	0.5908	0	Collapsed vessels	0.273	0.0399
Pith	0.5796	0	CD1	-0.3803	0.0035
Scar tissue	0.5736	0	*Quercus*	-0.4253	0.001
CD2	0.5256	0			
Prunus	0.4809	2.00E-04			
CD1	0.4688	2.00E-04			
Celtis	0.4513	4.00E-04			
Bark	0.3854	0.0031			
Artemisia	0.3706	0.0045			
Ulmaceae	0.3693	0.0047			
Leguminosae	0.36	0.0059			
Traumatic canals	0.3178	0.016			
Juniperus	-0.664	0			

Table 5.26d: Results of MFA run on Çatalhöyük per sample (dispersed and primary fuel waste contexts) wood charcoal taxon and dendrological counts: significant components of the first two dimensions. (ordered according to correlation value for each dimension, high to low).

	eigenvalue	% of variance	cumulative % of variance
comp 1	1.37698	37.80998	37.80998
comp 2	0.76259	20.93984	58.74982
comp 3	0.56617	15.54632	74.29614
comp 4	0.28887	7.93202	82.22816
comp 5	0.22144	6.08047	88.30863
comp 6	0.17759	4.87626	93.18489
comp 7	0.09351	2.56756	95.75245
comp 8	0.04913	1.34913	97.10157
comp 9	0.04041	1.10971	98.21128
comp 10	0.02372	0.65137	98.86265
comp 11	0.01634	0.44877	99.31142
comp 12	0.01056	0.28999	99.60141
comp 13	0.00525	0.14413	99.74554
comp 14	0.00304	0.08353	99.82907
comp 15	0.00238	0.06537	99.89445
comp 16	0.00160	0.04401	99.93845
comp 17	0.00083	0.02280	99.96125
comp 18	0.00056	0.01531	99.97656
comp 19	0.00044	0.01207	99.98863
comp 20	0.00018	0.00491	99.99354
comp 21	0.00013	0.00350	99.99704
comp 22	0.00006	0.00159	99.99863
comp 23	0.00003	0.00073	99.99937
comp 24	0.00001	0.00039	99.99976
comp 25	0.00001	0.00020	99.99996
comp 26	0.00000	0.00003	100.00000

Table 5.27a: Results of MFA run on Çatalhöyük per sample (primary fuel waste deposits) wood charcoal taxon counts and dung-derived seed counts: eigenvalues and percentage of variance of dimensions.

	Contribution to dimensions				
	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Charcoal	48.6898	85.0354	65.68	35.4749	18.6364
Dung.seed	51.3102	14.9646	34.32	64.5251	81.3636

Table 5.27b: Results of MFA run on Çatalhöyük per sample (primary fuel waste deposits) wood charcoal taxon counts and dung-derived seed counts: contribution of groups to dimensions.

		Contribution to dimensions				
		Dim.1	**Dim.2**	**Dim.3**	**Dim.4**	**Dim.5**
Wood charcoal taxa	*Juniperus*	**18.2101**	**65.4131**	0.1774	0.5073	0.3952
	Quercus	**26.8649**	6.9155	**60.0255**	1.3732	0.0703
	Amygdalus	0.0362	0.1048	0.0093	0.0758	0.0774
	Pistacia	2.00E-04	0	0.0035	0.0084	0.005
	Prunus	0	9.00E-04	2.00E-04	0.0066	0.0059
	Maloideae	0.0022	0.0018	0.0623	0.0039	0.0026
	Ulmaceae	3.00E-04	1.1861	1.3246	**12.9268**	7.1131
	Ulmus	0.0019	0.0732	0.0251	0.3445	0.2459
	Celtis	0.031	0.0158	0.5114	0.1787	7.00E-04
	Salicaceae	0.739	1.3726	3.537	19.4371	10.201
	Fraxinus	2.8035	9.9093	1.00E-04	0.2614	0.3222
	Tamarix	0	3.00E-04	3.00E-04	0.0023	0.0021
	Artemisia (charcoal)	5.00E-04	0.0408	0.0034	0.3387	0.1866
	Leguminosae (charcoal)	0	0.0012	1.00E-04	0.0101	0.0083
Dung-derived seed taxa	*Heliotropium*	0.007	0.0068	0.0013	8.00E-04	0.0028
	Chenopodium	0.994	0.6513	0.0559	4.1028	0.3383
	Salsola.type	0.0013	0	0.0038	0.0011	1.00E-04
	Suaeda	0.001	2.00E-04	6.00E-04	3.00E-04	7.00E-04
	Beta	0.1105	0.0573	0.021	0.0401	0.0368
	Helianthemum	0.0779	0.0299	0.0038	0.0134	0.0533
	Artemisia (seed)	2.00E-04	0	8.00E-04	5.00E-04	0.1044
	Bolboschoenus glaucus	**46.2791**	**13.7255**	**29.7159**	0.2395	3.2945
	Carex	0.7022	0.0758	0.2922	**54.4801**	**18.314**
	Aeluropus	0.0139	0.0073	1.00E-04	0.5396	0.9271
	Crypsis	0.0052	0.013	0.0051	0.0214	0.0111
	Sporobolus	0.0367	0.0513	1.00E-04	0.8705	0.8265
	Juncus	0.5723	0.2705	0.0895	1.6988	**55.6853**
	Ziziphora	2.00E-04	0	6.00E-04	2.00E-04	0
	Leguminosae (seed)	2.5074	0.0661	4.1078	1.8727	1.6479
	Polygonum aviculare	0.0011	0.0097	0.0214	0.6433	0.1209
	Potamogeton	1.00E-04	0	0	0	0

Table 5.27c: Results of MFA run on Çatalhöyük per sample (primary fuel waste deposits) wood charcoal taxon counts and dung-derived seed counts: contribution of variables to dimensions.

	Dim.1	
	correlation	**p value**
Bolboschoenus glaucus	0.8315	0
Beta	0.7353	0
Potamogeton	0.732	0
Quercus	0.6921	0
Helianthemum	0.6363	2.00E-04
Leguminosae (seed)	0.5762	9.00E-04
Chenopodium	0.4998	0.0049
Heliotropium	0.4169	0.0219
Suaeda	0.3866	0.0348
Fraxinus	-0.4453	0.0137
Juniperus	-0.5717	0.001

	Dim.2	
	correlation	**p value**
Juniperus	0.8063	0
Fraxinus	0.623	2.00E-04
Potamogeton	0.398	0.0294
Beta	0.3941	0.0312
Amygdalus	0.3787	0.039

Table 5.27d: Results of MFA run on Çatalhöyük per sample (primary fuel waste deposits) wood charcoal taxon counts and dung-derived seed counts: significant variables for the first two dimensions. (ordered according to correlation value for each dimension, high to low).

	eigenvalue	% of variance	cumulative % of variance
comp 1	1.164528	42.97899	42.97899
comp 2	0.985295	36.36408	79.34308
comp 3	0.231367	8.539002	87.88208
comp 4	0.133054	4.910584	92.79266
comp 5	0.088058	3.24992	96.04258
comp 6	0.034255	1.264244	97.30683
comp 7	0.022333	0.824237	98.13106
comp 8	0.01281	0.472769	98.60383
comp 9	0.009693	0.357745	98.96158
comp 10	0.008444	0.311623	99.2732
comp 11	0.006376	0.23531	99.50851
comp 12	0.003439	0.126933	99.63544
comp 13	0.002714	0.100152	99.7356
comp 14	0.002164	0.079859	99.81545
comp 15	0.001767	0.065218	99.88067
comp 16	0.001527	0.056349	99.93702
comp 17	0.000501	0.018505	99.95553
comp 18	0.000394	0.01454	99.97007
comp 19	0.000334	0.01232	99.98239
comp 20	0.000191	0.007041	99.98943
comp 21	0.000159	0.005886	99.99531
comp 22	5.91E-05	0.002181	99.99749
comp 23	3.33E-05	0.00123	99.99872
comp 24	1.42E-05	0.000524	99.99925
comp 25	1.35E-05	0.000498	99.99975
comp 26	5.02E-06	0.000185	99.99993
comp 27	1.30E-06	4.78E-05	99.99998
comp 28	3.25E-07	1.20E-05	99.99999
comp 29	1.57E-07	5.79E-06	100

Table 5.28a: Results of MFA run on Çatalhöyük per sample (dispersed contexts) wood charcoal taxon counts and dung-derived seed counts: eigenvalues and percentage of variance.

	Contribution to dimensions				
	Dim.1	**Dim.2**	**Dim.3**	**Dim.4**	**Dim.5**
Charcoal	25.0199	88.4703	78.1829	57.6299	64.9633
Dung seed	74.9801	11.5297	21.8171	42.3701	35.0367

Table 5.28b: Results of MFA run on Çatalhöyük per sample (dispersed contexts) wood charcoal taxon counts and dung-derived seed counts: contribution of each group to dimensions.

		Contribution to dimensions				
		Dim.1	**Dim.2**	**Dim.3**	**Dim.4**	**Dim.5**
Wood charcoal taxa	*Juniperus*	0.557	**11.784**	**48.150**	**34.240**	3.315
	Quercus	**15.619**	**71.244**	8.703	1.039	0.000
	Amygdalus	0.009	0.190	0.386	0.074	0.082
	Pistacia	0.003	0.033	0.003	0.204	1.215
	Prunus	0.001	0.001	0.000	0.002	0.003
	Maloideae	0.001	0.002	0.018	0.011	0.022
	Ulmaceae	**8.728**	0.858	**9.121**	**14.120**	**21.147**
	Ulmus	0.043	0.022	6.803	5.250	0.650
	Celtis	0.000	0.433	1.932	0.356	11.573
	Salicaceae	0.002	3.594	2.981	1.155	**25.707**
	Fraxinus	0.041	0.276	0.000	1.010	0.489
	Tamarix	0.000	0.000	0.000	0.002	0.014
	Artemisia (charcoal)	0.000	0.008	0.039	0.046	0.469
	Leguminosae (charcoal)	0.016	0.027	0.046	0.123	0.278
Dung-derived seed taxa	*Aeluropus*	0.508	0.020	0.107	0.278	0.316
	Alisma	0.000	0.000	0.003	0.006	0.001
	Crypsis	0.001	0.015	0.002	0.007	0.000
	Artemisia (seed)	0.000	0.000	0.000	0.000	0.000
	Beta	0.000	0.000	0.000	0.000	0.001
	Bolboschoenus glaucus	**23.203**	6.789	1.360	**26.257**	**26.980**
	Carex	0.001	0.001	0.000	0.014	0.011
	Chenopodium	0.002	0.027	0.000	0.023	0.034
	Cyperaceae	0.006	0.002	0.000	0.033	0.039
	Helianthemum	0.008	0.010	0.001	0.001	0.026
	Heliotropium	0.033	0.002	0.027	0.014	0.006
	Juncus	0.016	0.002	0.048	0.009	1.274
	Leguminosae (seed)	**51.163**	4.611	**20.215**	**15.693**	2.881
	Polygonum aviculare	0.001	0.000	0.000	0.002	0.002
	Salsola	0.000	0.000	0.002	0.006	0.005
	Sporobolus	0.039	0.052	0.052	0.026	3.454
	Suaeda	0.000	0.000	0.000	0.000	0.000
	Ziziphora	0.000	0.000	0.000	0.000	0.007

Table 5.28c: Results of MFA run on Çatalhöyük per sample (dispersed contexts) wood charcoal taxon counts and dung-derived seed counts: contribution of each variable to dimensions.

Dim.1			**Dim.2**		
	correlation	**p value**		**correlation**	**p value**
Leguminosae (seed)	0.9143	0	*Quercus*	0.88	0
Heliotropium	0.8434	0	Salicaceae	0.6731	0
Bolboschoenus glaucus	0.819	0	*Bolboschoenus glaucus*	0.4075	0.0206
Aeluropus	0.8064	0	*Celtis* (charcoal)	0.4024	0.0224
Ulmaceae	0.7606	0	*Fraxinus*	-0.3823	0.0308
Beta	0.5125	0.0027	*Amygdalus*	-0.4288	0.0143
Polygonum aviculare	0.4079	0.0205	*Juniperus*	-0.6408	1.00E-04
Quercus	-0.448	0.0101			

Table 5.28d: Results of MFA run on Çatalhöyük per sample (dispersed contexts) wood charcoal taxon counts and dung-derived seed counts: significant variables in the first two dimensions. (ordered according to correlation value for each dimension, high to low).

		S. G	S. G-H	S. K	S. L	S. M	S. P	S. Q	S. R	S. S	S. T
Wood charcoal taxa	*Juniperus*	9	7	23	28	20	42	104	116	294	91
	Quercus	31	651	371	636	253	270	83	53	48	28
	Amygdalus	21	4	7	8	1	8	11	23	35	12
	Pistacia	39	19	26	19	14	6	10	7	15	13
	Prunus	1	2	0	8	2	2	0	0	0	0
	Maloideae	16	19	68	19	4	6	0	0	0	0
	Ulmaceae	473	119	110	61	5	96	27	25	7	13
	Ulmus	86	28	37	70	38	22	11	4	4	1
	Celtis	132	126	67	69	11	17	5	7	1	0
	Salicaceae	281	226	127	146	31	102	21	3	2	5
	Fraxinus	0	1	7	24	2	3	23	41	28	9
	Acer	0	0	2	5	2	0	0	1	2	0
	Tamarix	3	0	1	1	3	4	1	0	0	0
	Labiatae	5	0	6	5	1	0	0	0	0	0
	Artemisia (charcoal)	14	15	11	8	2	6	2	0	1	0
	Chenopodiaceae (charcoal)	7	9	10	18	3	0	0	0	0	0
	Leguminosae (charcoal)	1	8	38	31	2	1	0	0	0	0
	Capparis	0	1	4	1	1	2	0	0	0	0
Dung-derived seed taxa	*Aeluropus*	352	8	16	110	8	168	144	36	0	24
	Alisma	9	0	4	0	0	8	0	0	0	0
	Artemisia	2	1	0	32	0	20	40	8	9	40
	Beta	6	2	0	1	0	0	0	0	0	0
	Bolboschoenus glaucus	2417	519	265	645	64	257.0625	211	50	159	2341
	Carex	1	61	2	55	4	79.5	141	40	4	872
	Chenopodium	21	29	0	145	4	20	20	9	10	8
	Cyperaceae	0	20	33	109	4	152.5	210	110	37	781
	Helianthemum	56	65	24	8	0	12	0	0	0	1
	Heliotropium	47	1	0	0	8	8	16	4	2	32
	Juncus	121	48	0	0	0	172	188	80	0	48
	Leguminosae (seeds)	2561	258	59	551	69	651.5	63	2	3	17
	Polygonum aviculare	12	1	24	42	0	21.5	25	3	17	19
	Salsola type	8	4	0	2	0	0	0	1	1	0
	Sporobolus	179	0	48	28	0	208	256	176	49	1408
	Suaeda	2	0	0	0	1	0	8	0	8	0
	Ziziphora	10	0	0	0	0	0	0	0	0	0
	Crypsis	0	0	0	0	0	440	136	116	10	224
Faunal taxa	*Bos*	422	180	360	966	513	295	561	242	699	49
	Ovis/Capra	3083	1297	971	2464	1390	2046	3911	3562	8856	693
	Ovis	161	107	101	224	522	314	487	313	1056	78
	Capra	52	11	21	54	27	57	82	40	169	8
	Equus	27	64	41	228	74	5	14	0	4	2
	S-M Equid	41	45	30	133	107	47	56	11	27	0
	L Cervid	13	13	28	48	144	5	9	12	9	2
	Sus scrofa	143	46	68	238	89	21	36	8	55	8

Table 5.29: Çatalhöyük per phase counts of wood charcoal, dung-derived seed and faunal taxa (counted by NISP) included in MFA.

	eigenvalue	% of variance	cumulative % of variance
comp 1	1.533597	38.26	38.26
comp 2	1.358735	33.9	72.16
comp 3	0.787078	19.64	91.79
comp 4	0.250134	6.24	98.03
comp 5	0.038345	0.96	98.99
comp 6	0.025445	0.63	99.62
comp 7	0.007452	0.19	99.8
comp 8	0.004769	0.12	99.93
comp 9	0.002927	0.07	100

Table 5.30a: Results of MFA run on Çatalhöyük per phase wood charcoal taxon counts, dung-derived seed counts and faunal counts (by NISP): eigenvalues and percentage of variance for dimensions.

	Contribution to dimensions				
	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Dung seeds	18.4679	49.9491	42.5807	48.1168	55.5298
Fauna	46.6677	4.1818	24.473	16.0705	6.0991
Charcoal	34.8644	45.8691	32.9462	35.8128	38.3711

Table 5.30b: Results of MFA run on Çatalhöyük per phase wood charcoal taxon counts, dung-derived seed counts and faunal counts (by NISP): contribution of each group to dimensions.

		Contribution to dimensions				
		Dim.1	**Dim.2**	**Dim.3**	**Dim.4**	**Dim.5**
Dung-derived seed taxa	*Aeluropus*	0.08	0.3267	0.2133	0.2369	3.7278
	Alisma	1.00E-04	2.00E-04	2.00E-04	7.00E-04	8.00E-04
	Artemisia	1.00E-04	1.00E-04	0.0065	0.0137	0.1797
	Beta	1.00E-04	1.00E-04	1.00E-04	0	1.00E-04
	Bolboschoenus glaucus	**10.7794**	**29.5861**	3.3559	**29.9395**	1.2132
	Carex	0.0723	0.3376	5.0496	4.4998	0.4917
	Chenopodium	0.0074	0.008	0.0234	0.1388	1.0396
	Cyperaceae	0.0114	0.2285	4.0607	2.7947	2.7764
	Helianthemum	0.0131	8.00E-04	0.0156	8.00E-04	0.2128
	Heliotropium	0.0013	0.0123	7.00E-04	1.00E-04	0.0015
	Juncus	1.00E-04	0.0384	3.00E-04	0.292	1.6731
	Leguminosae (seeds)	**7.3882**	**17.477**	**17.0204**	3.1014	**28.367**
	Polygonum aviculare	0	0	1.00E-04	0.0082	0.0752
	Salsola type	1.00E-04	1.00E-04	3.00E-04	0	4.00E-04
	Sporobolus	0.1122	1.9244	**12.399**	6.8632	1.4437
	Suaeda	3.00E-04	0	1.00E-04	0	0
	Ziziphora	1.00E-04	4.00E-04	2.00E-04	1.00E-04	1.00E-04
	Crypsis	0.0017	0.0085	0.4343	0.2269	14.3267
Faunal taxa	*Bos*	0.0614	0.0292	0.5071	0.2094	4.906
	Ovis/Capra	**45.7827**	4.1323	**23.777**	**15.7612**	0.1011
	Ovis	0.79	0	0.127	0.0137	0.4291
	Capra	0.0164	0.0011	0.0096	0.006	0.0251
	Equus	0.0082	0.0121	0.0119	0.0435	0.232
	S.M. Equid	0.001	0.0041	0.0051	0	0.1977
	L. Cervid	2.00E-04	0.0029	0	0.012	0.0103
	Sus scrofa	0.0077	0	0.0353	0.0247	0.1977
Wood charcoal taxa	*Juniperus*	6.5057	0.2509	7.00E-04	4.485	1.7076
	Quercus	**15.4122**	**36.0441**	**12.8227**	**27.6024**	2.1715
	Amygdalus	0.049	0.037	0.0135	0.0251	0.0853
	Pistacia	0.0248	0.0225	0.045	0.0034	0.6099
	Prunus	9.00E-04	0.001	0.0015	0.0046	0.0769
	Maloideae	0.084	0.0383	0.035	0.0295	4.3002
	Ulmaceae	5.4672	**9.0445**	**10.0797**	3.2098	**10.8527**
	Ulmus	0.3343	0.0372	0.5726	0.0112	0.7297
	Celtis	1.3386	0.0335	1.8677	0.2266	10.414
	Salicaceae	5.4909	0.2997	7.45	0.1417	6.9579
	Fraxinus	0.0961	0.0022	1.00E-04	0.0139	0.0477
	Acer	0	6.00E-04	4.00E-04	0.0014	0.0048
	Tamarix	2.00E-04	1.00E-04	2.00E-04	0.0045	0.0245
	Labiatae	0.0016	1.00E-04	0.002	0	0.0049
	Artemisia (charcoal)	0.0171	0	0.0233	4.00E-04	0.1076
	Chenopodiaceae (charcoal)	0.0132	0.0046	0.0161	0.0243	0.001
	Leguminosae (charcoal)	0.0285	0.0525	0.016	0.0282	0.2722
	Capparis	2.00E-04	5.00E-04	0	7.00E-04	0.0028

Table 5.30c: Results of MFA run on Çatalhöyük per phase wood charcoal taxon counts, dung-derived seed counts and faunal counts (by NISP): contribution to dimensions of variables.

Dim.1			**Dim.2**		
	correlation	**p value**		**correlation**	**p value**
Salicaceae	0.742	0.014	*Heliotropium*	0.9074	3.00E-04
Artemisia (charcoal)	0.7135	0.0205	*Ziziphora*	0.7988	0.0056
Celtis	0.7086	0.0218	*Bolboschoenus glaucus*	0.7742	0.0086
Helianthemum	0.6427	0.0451	Leguminosae (seed)	0.6866	0.0283
Ulmus	0.6362	0.048	*Aeluropus*	0.6616	0.0372
Amygdalus	-0.6781	0.0312	Ulmaceae	0.6401	0.0462
Fraxinus	-0.6929	0.0263	*Quercus*	-0.7389	0.0146
Suaeda	-0.7344	0.0156			
Capra	-0.8089	0.0046			
Ovis/*Capra*	-0.8443	0.0021			
Ovis	-0.8911	5.00E-04			
Juniperus	-0.9253	1.00E-04			

Table 5.30d: Results of MFA run on Çatalhöyük per phase wood charcoal taxon counts, dung-derived seed counts and faunal counts (by NISP): significant components of the first two dimensions. (ordered according to correlation value for each dimension, high to low).

	High woodland density		**Low woodland density**	
	Low diversity	**High diversity**	**Low diversity**	**High diversity**
Fuel wood collection mode	*Selective*	*Selective*	*Non-selective*	*Non-selective*
Predicted diversity of the anthracological assemblage	Low	Low	Low	High
Evenness in anthracological assemblage	Few taxa dominate fuel wood use	Few taxa dominate fuel wood use	Few taxa dominate fuel wood use	Wide range of taxa dominate fuel wood use
Predicted location of fuel wood collection	Proximate	Proximate	Proximate-distant	Proximate-distant

Table 6.1 Inferred impacts of selective and non-selective fuel wood collection strategies on the diversity and evenness of anthracological fuel wood assemblages, under conditions of high and low woodland density (defined as per capita wood fuel requirements) according to the Principle of Least Effort (cf. Shackleton and Prins 1992).

General category of subsistence economy	Mobile hunter-gatherers	Pastoral nomads	Settled agro-pastoral communities
Fuel collection catchments	Possibly close to habitation	Most likely close to habitation	Variable (proximate and more distant)
Fuel economy	Opportunistic	Opportunistic	Scheduled, cyclical (seasonal)
Fuel choice characterisation	Possibly non-selective	Possibly non-selective	Possibly selective

Table 6.2 Simplified fuel collection model (based on Asouti and Austin 2005: Tables 2-4).

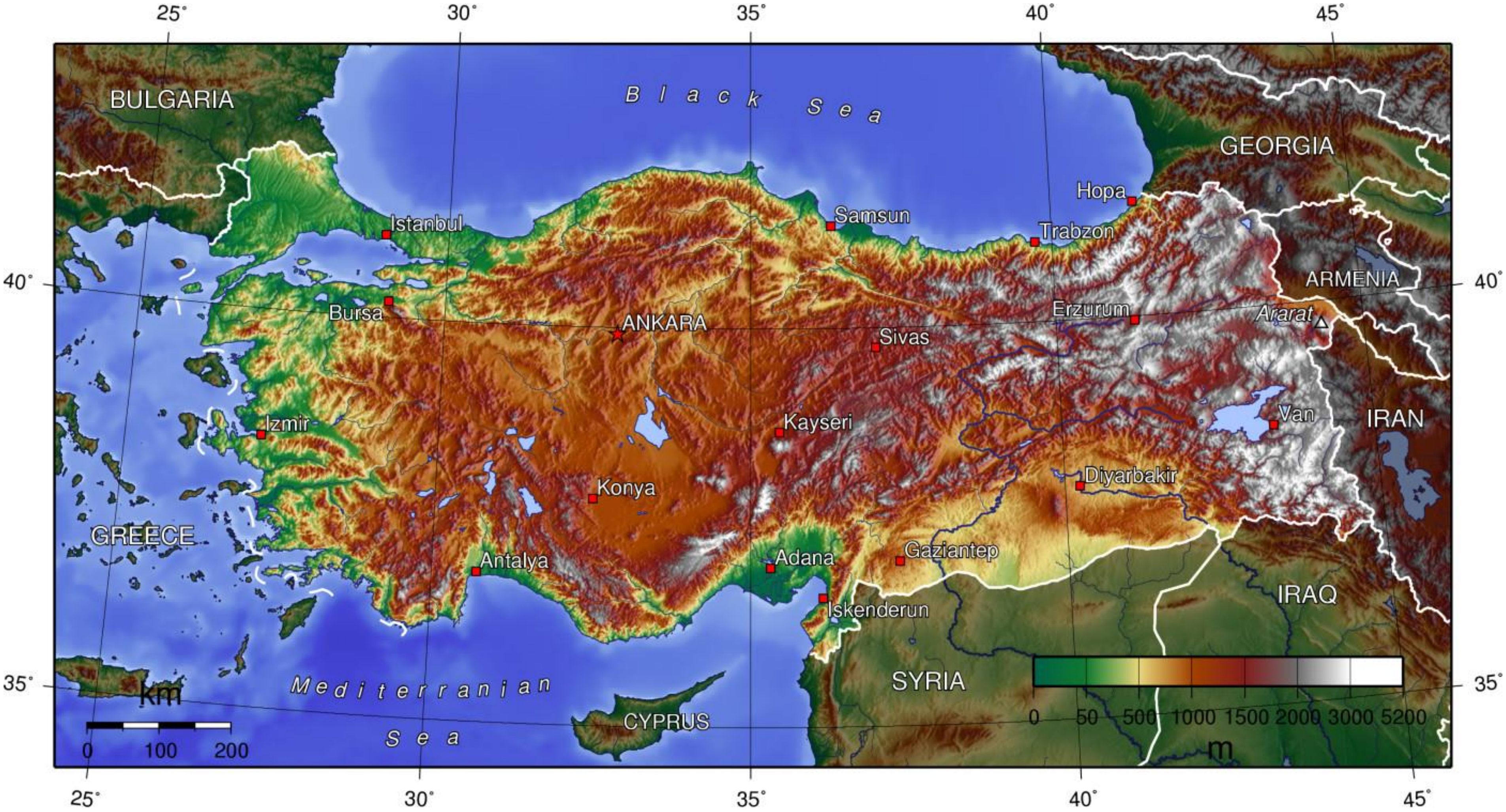

Figure 2.1: Topographic map of Turkey showing main landforms and elevation.

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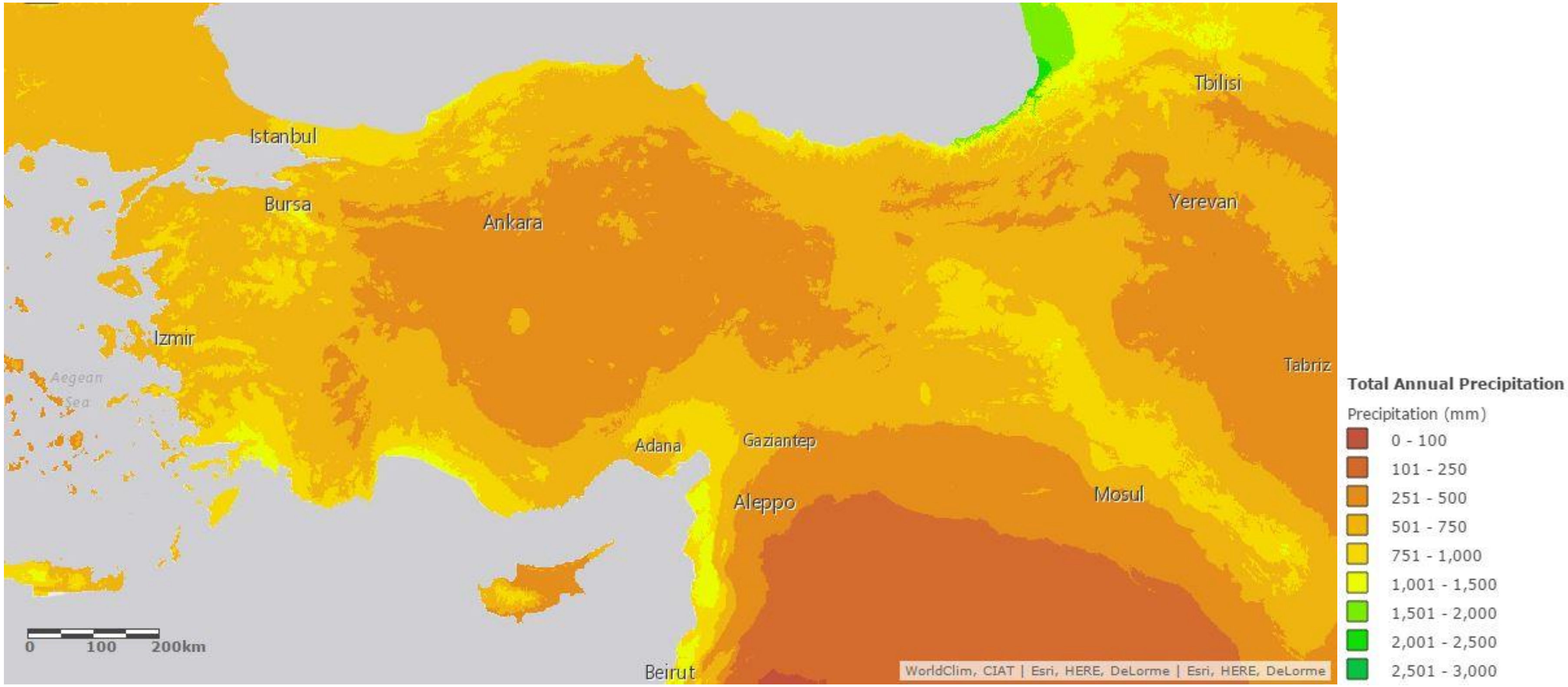


Figure 2.2: Average annual rainfall map of Turkey and adjacent regions. (after, WorldClim, CIAT, Hijmans *et al*. 2005)

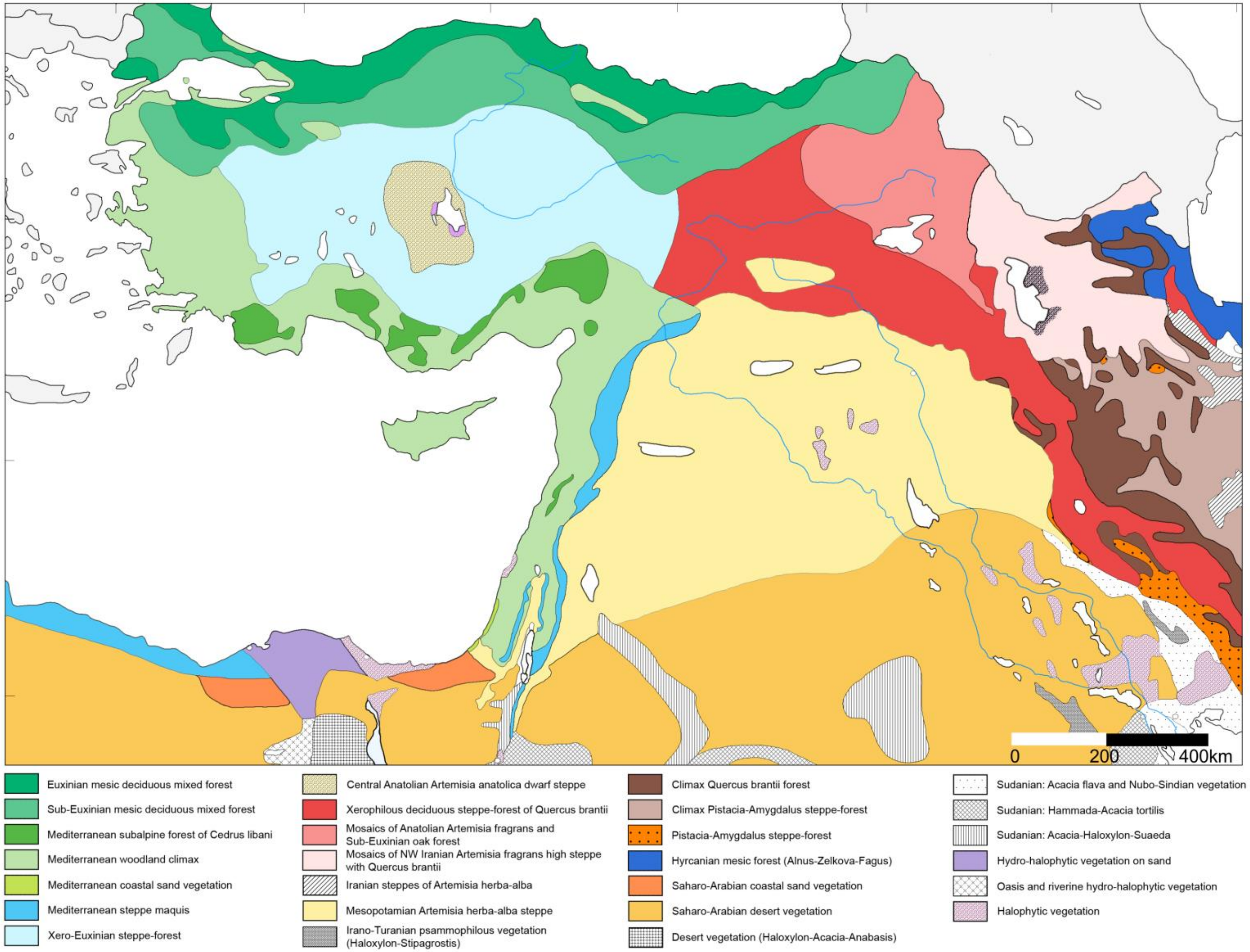


Figure 2.3: Map of the major bioclimatic regions and associated phytogeographical zones of Southwest Asia (modified after Zohary 1973).

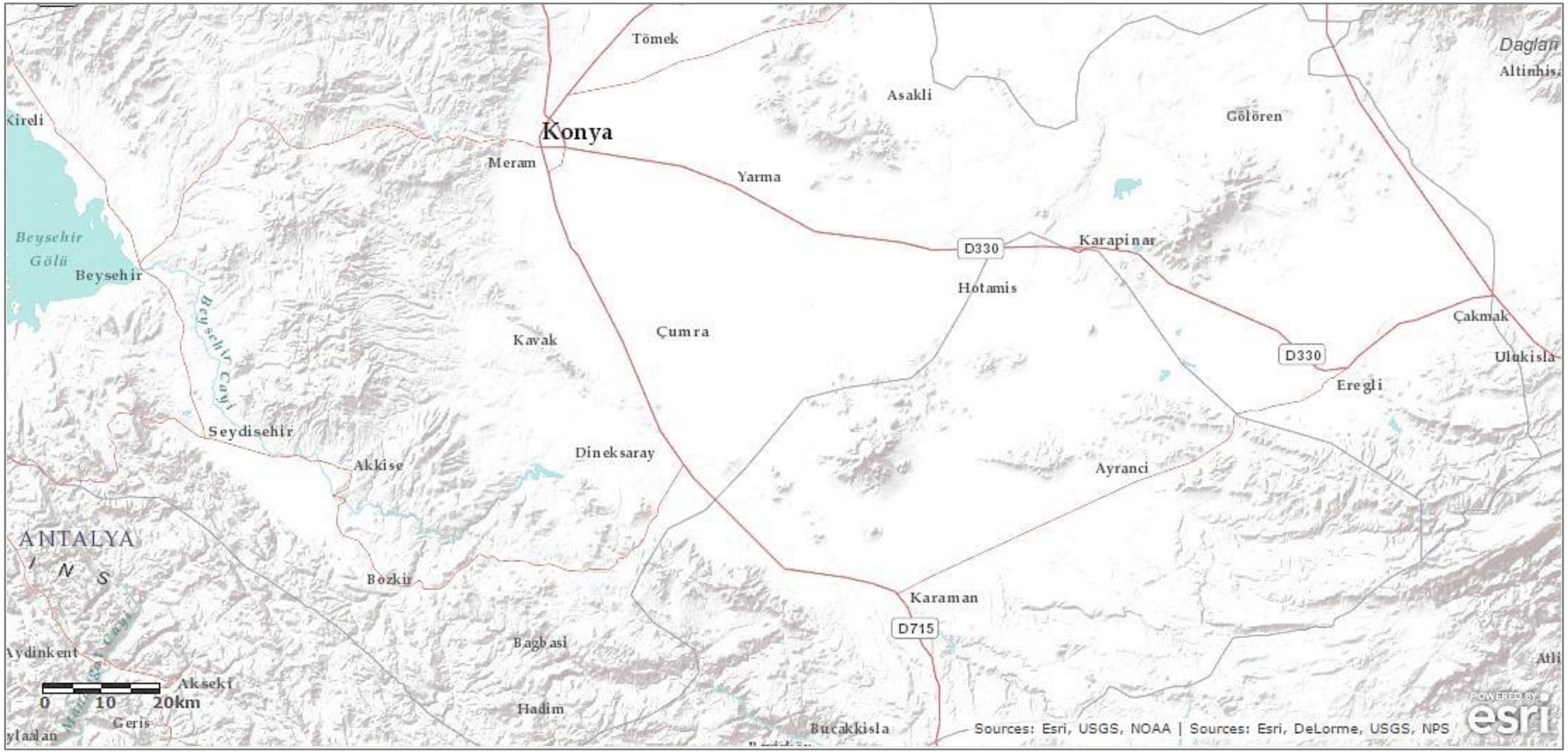


Figure 2.4: Map of the Konya plain.

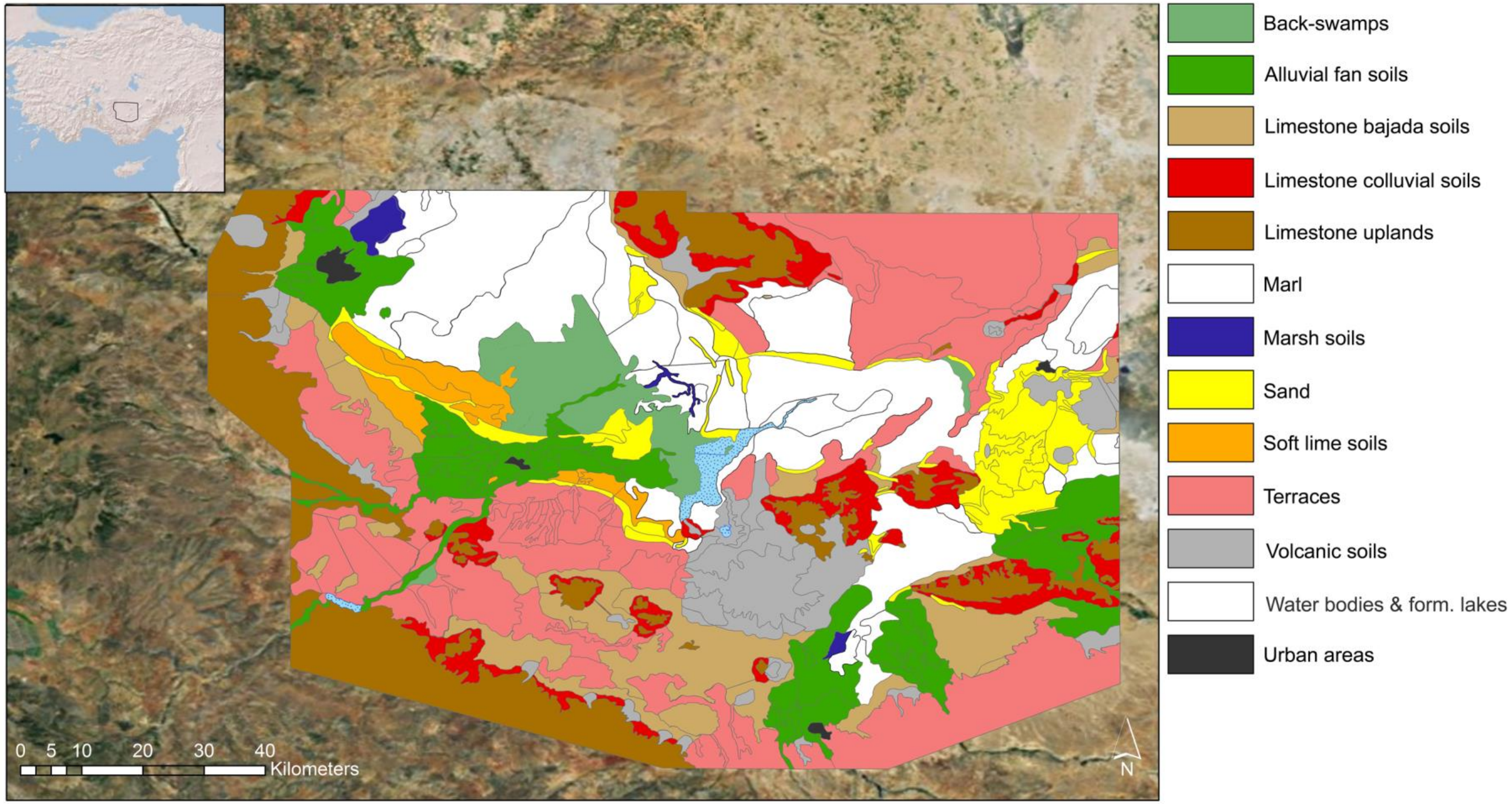


Figure 2.5: Map of major soil types and sedimentary units of the Konya plain (after Asouti and Kabukcu 2014)

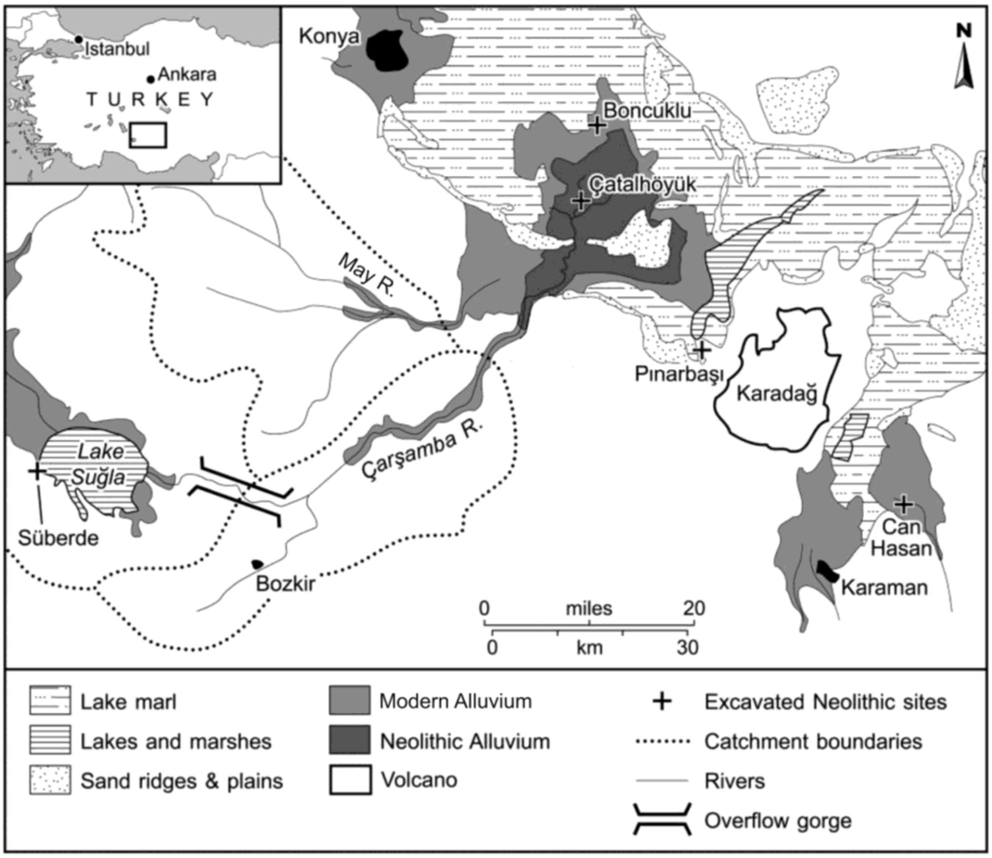


Figure 2.6: Outline map of the May and Çarşamba rivers catchment areas and major landscape units of the Konya plain (adapted from Roberts and Rosen 2009:Fig. 1).

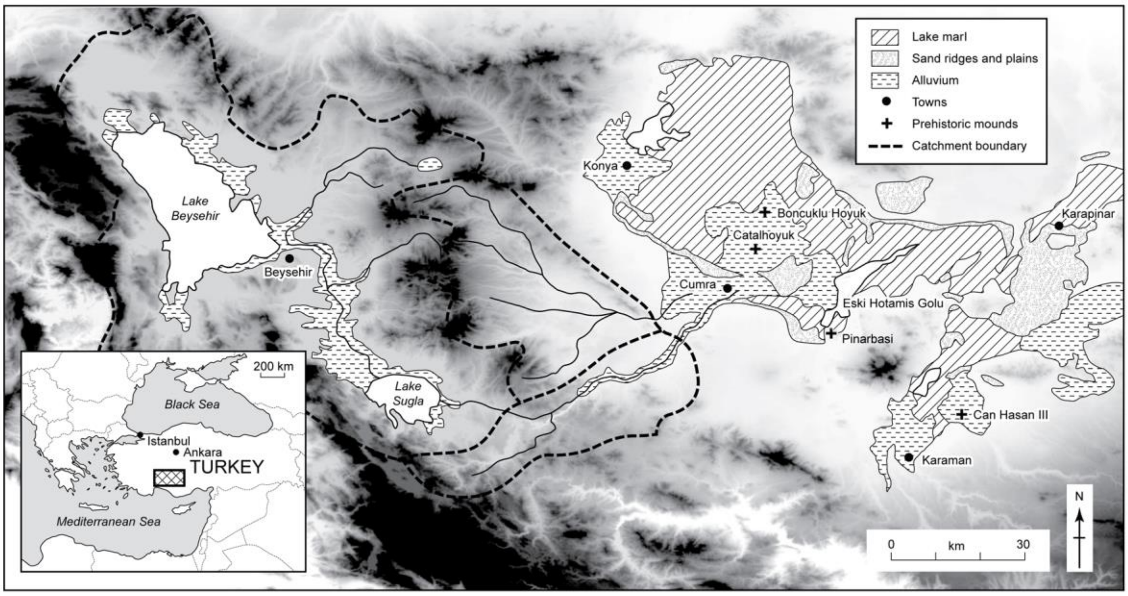


Figure 2.7: Map of the broader Çarşamba river catchment area.

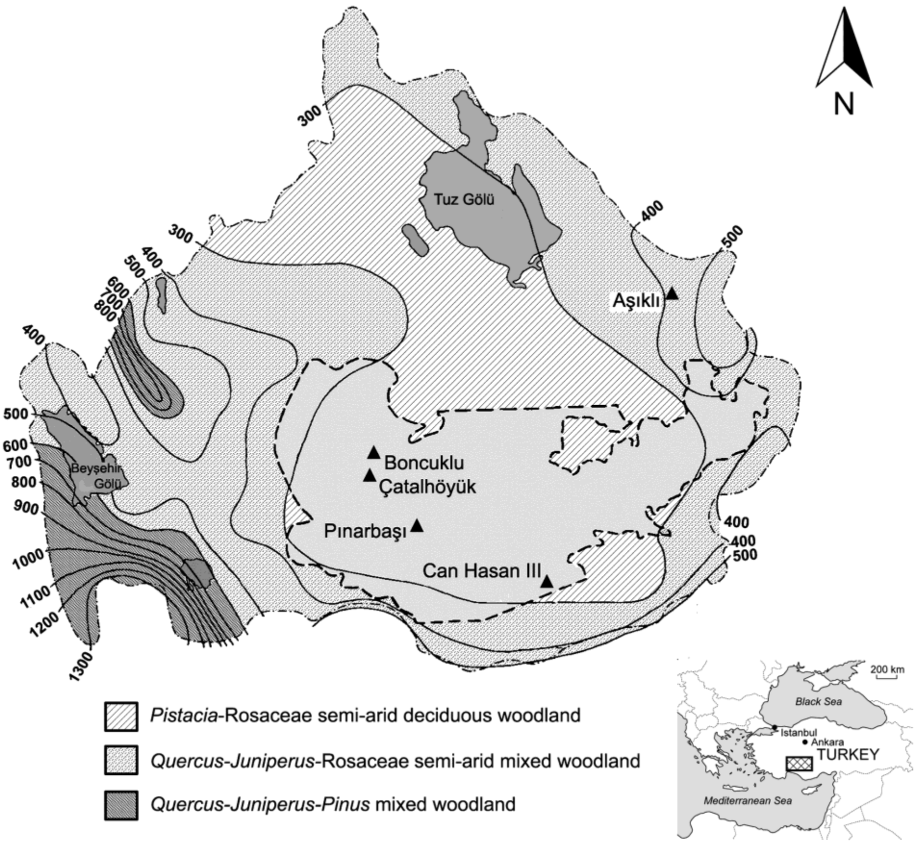


Figure 2.8: Schematic map of major rainfall gradients and associated vegetation zones in the Konya plain (after Asouti and Kabukcu 2014)

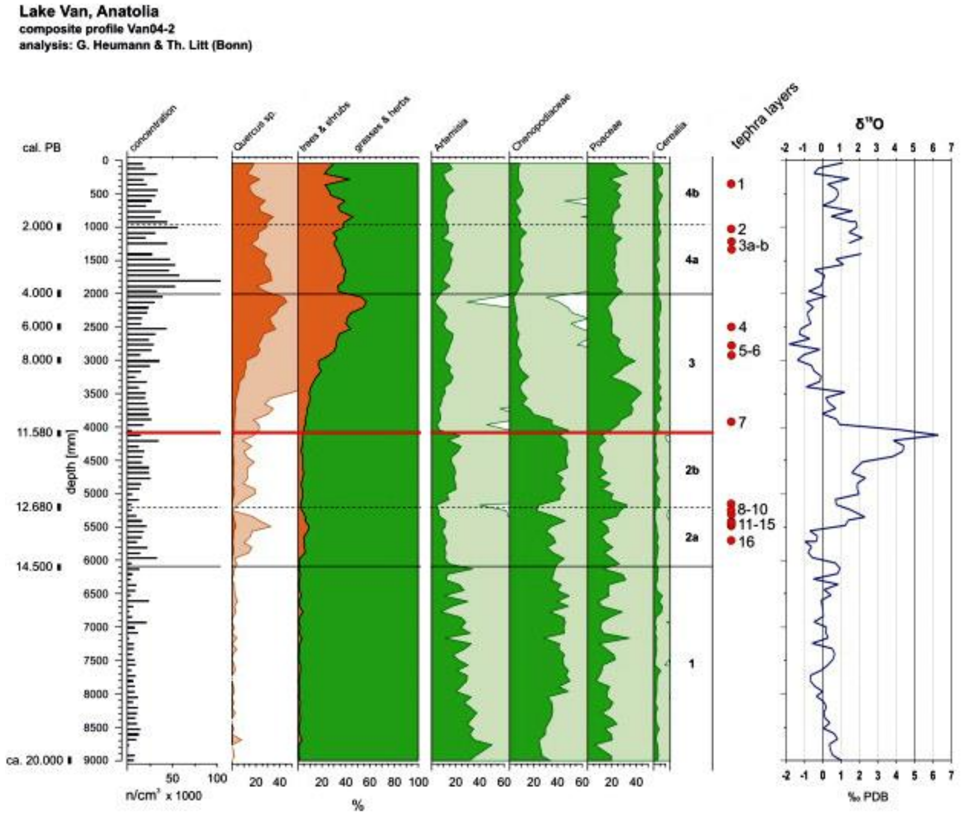


Figure 2.9: Main pollen curves and associated oxygen isotope values from the Lake Van (after Litt et al. 2009)

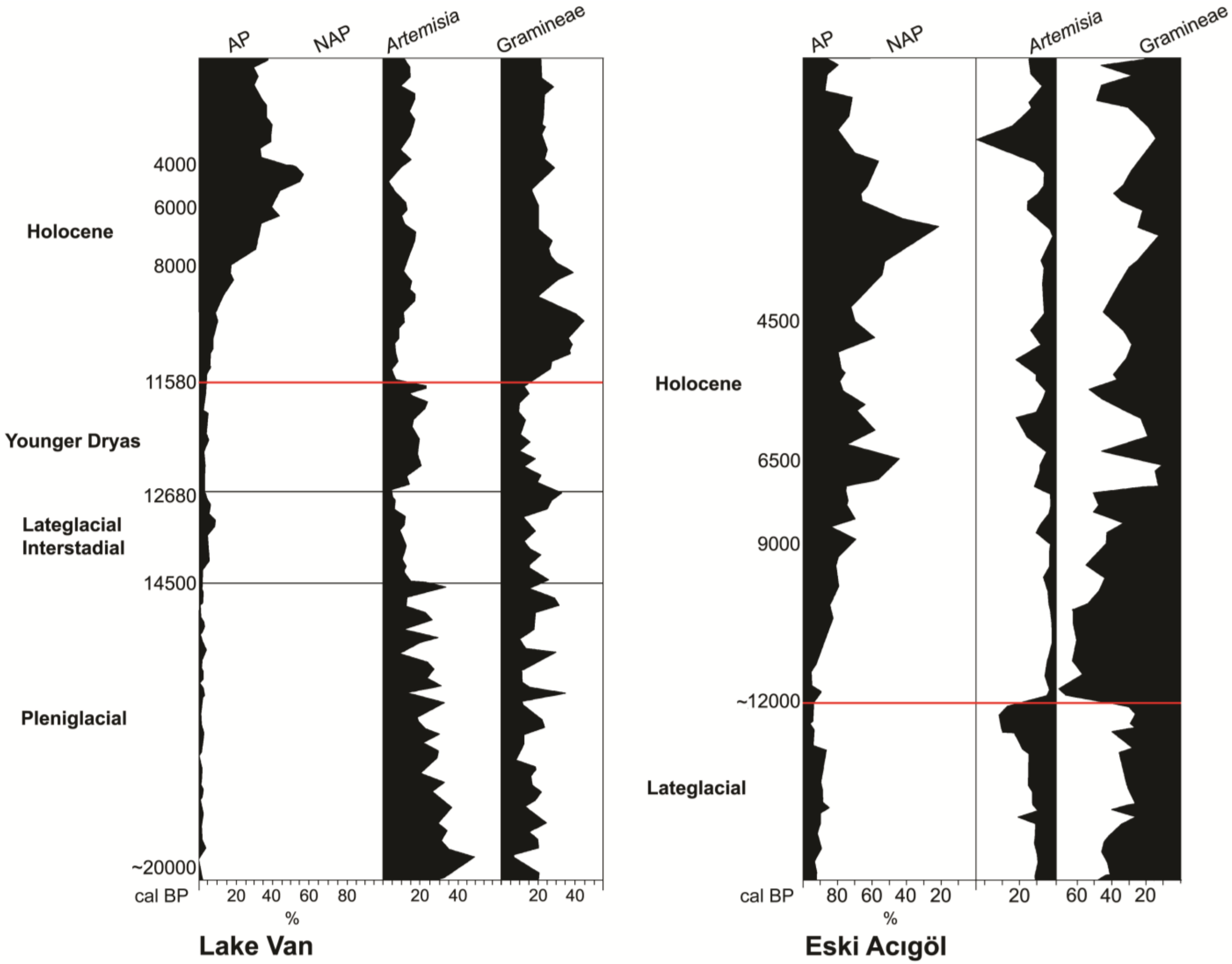


Figure 2.10: Comparison of the main pollen curves from the Lake Van and the Eski Acıgöl sequences (after Asouti and Kabukcu 2014)

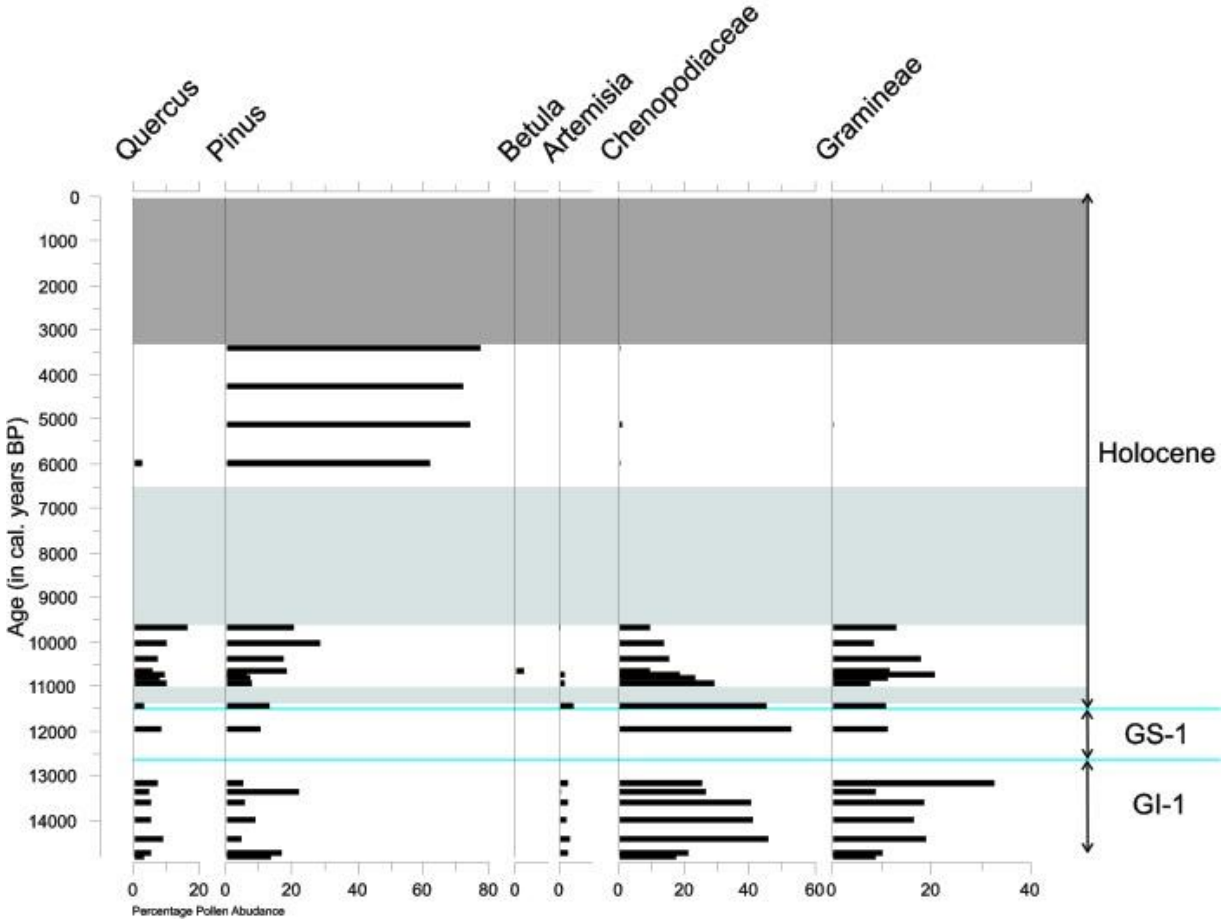


Figure 2.11: Summary pollen diagram from Akgöl Adabağ (core AGL95) (shaded parts denote gaps in sedimentation) (as reported by Turner et al. 2010).

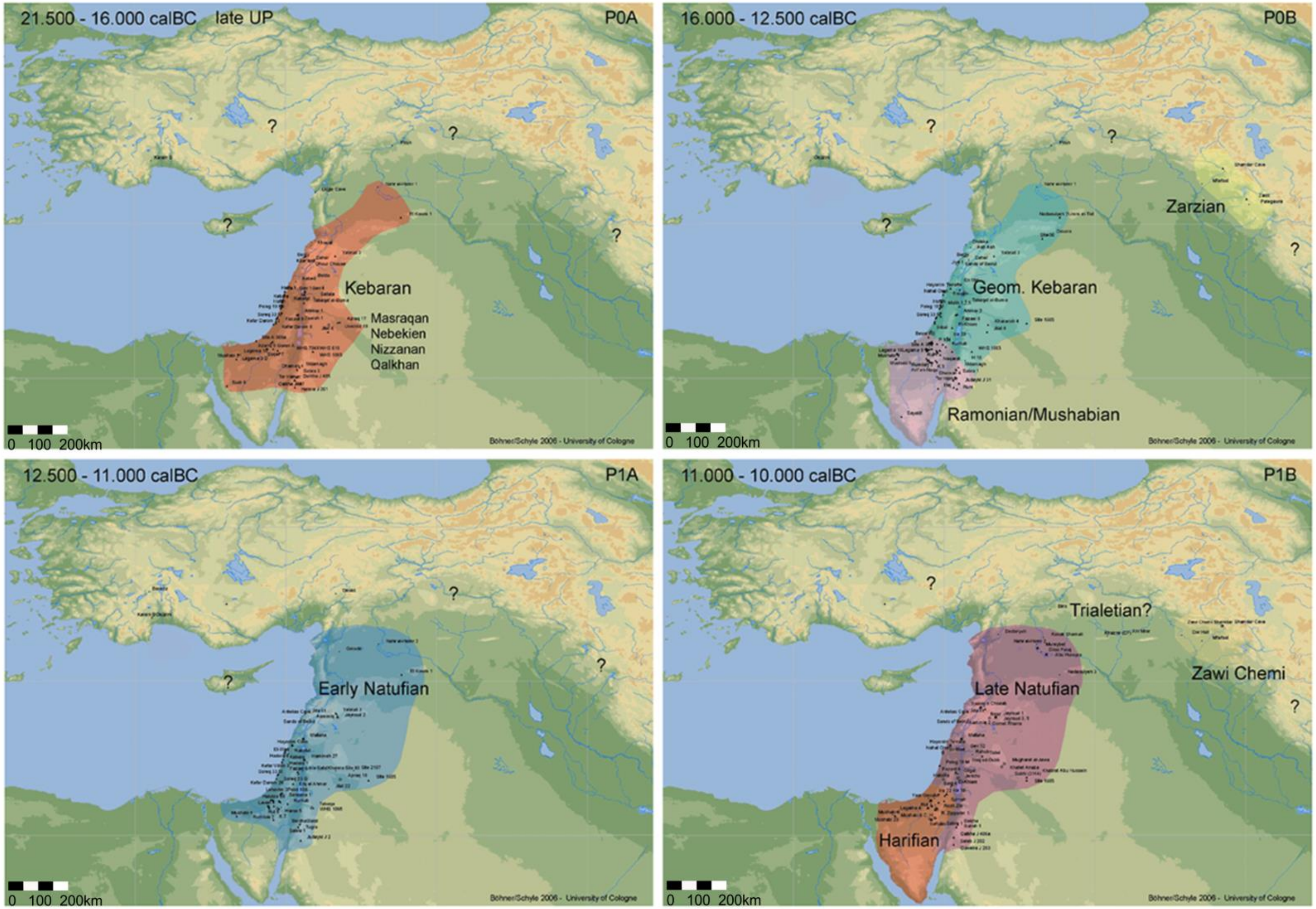


Figure 3.1a: Main cultural entities in Southwest Asia 21,500-10,000 cal BC (source: radiocarbon CONTEXT database).

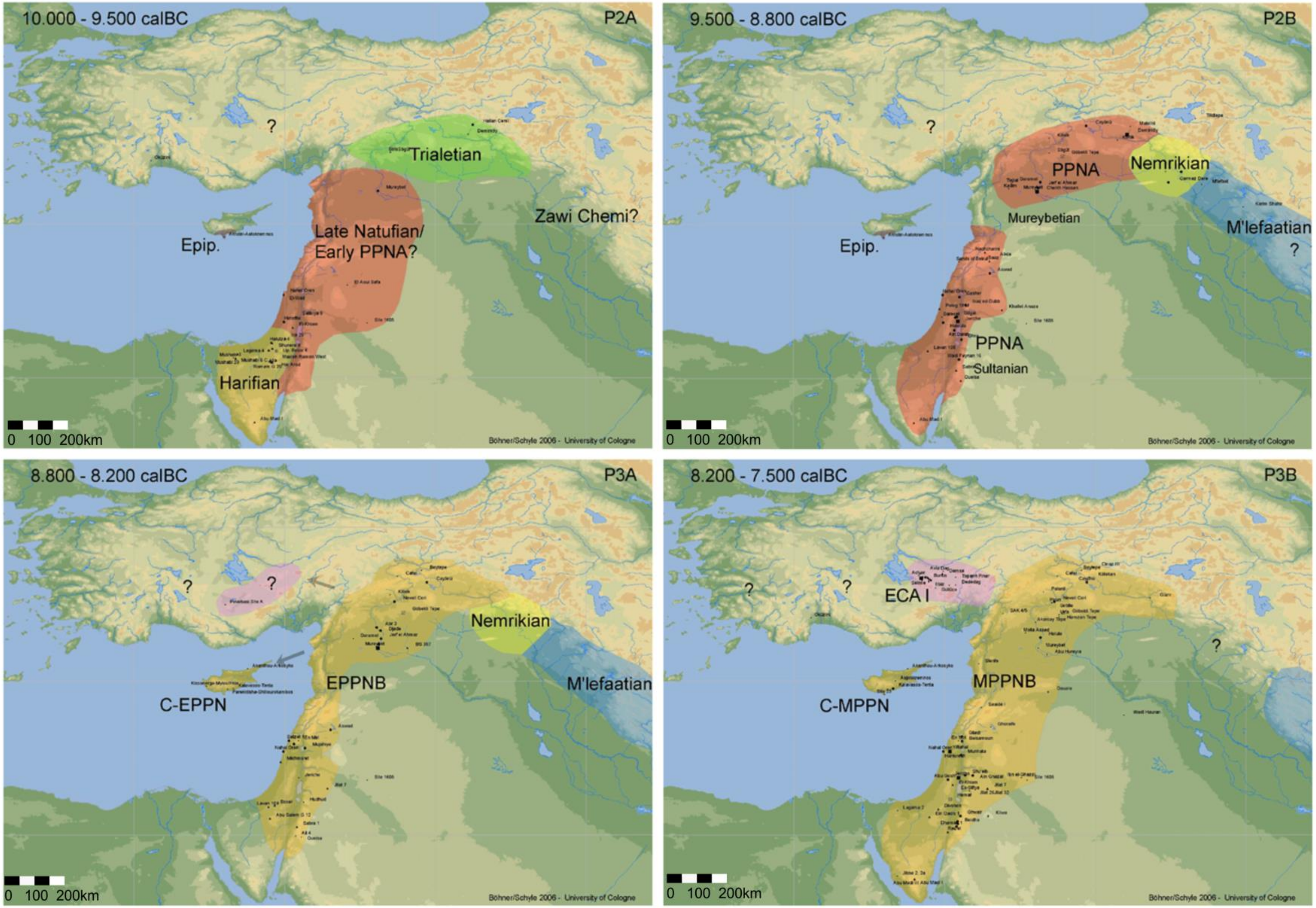


Figure 3.1b: Main cultural entities in Southwest Asia 10,500-7500 cal BC (source: radiocarbon CONTEXT database).

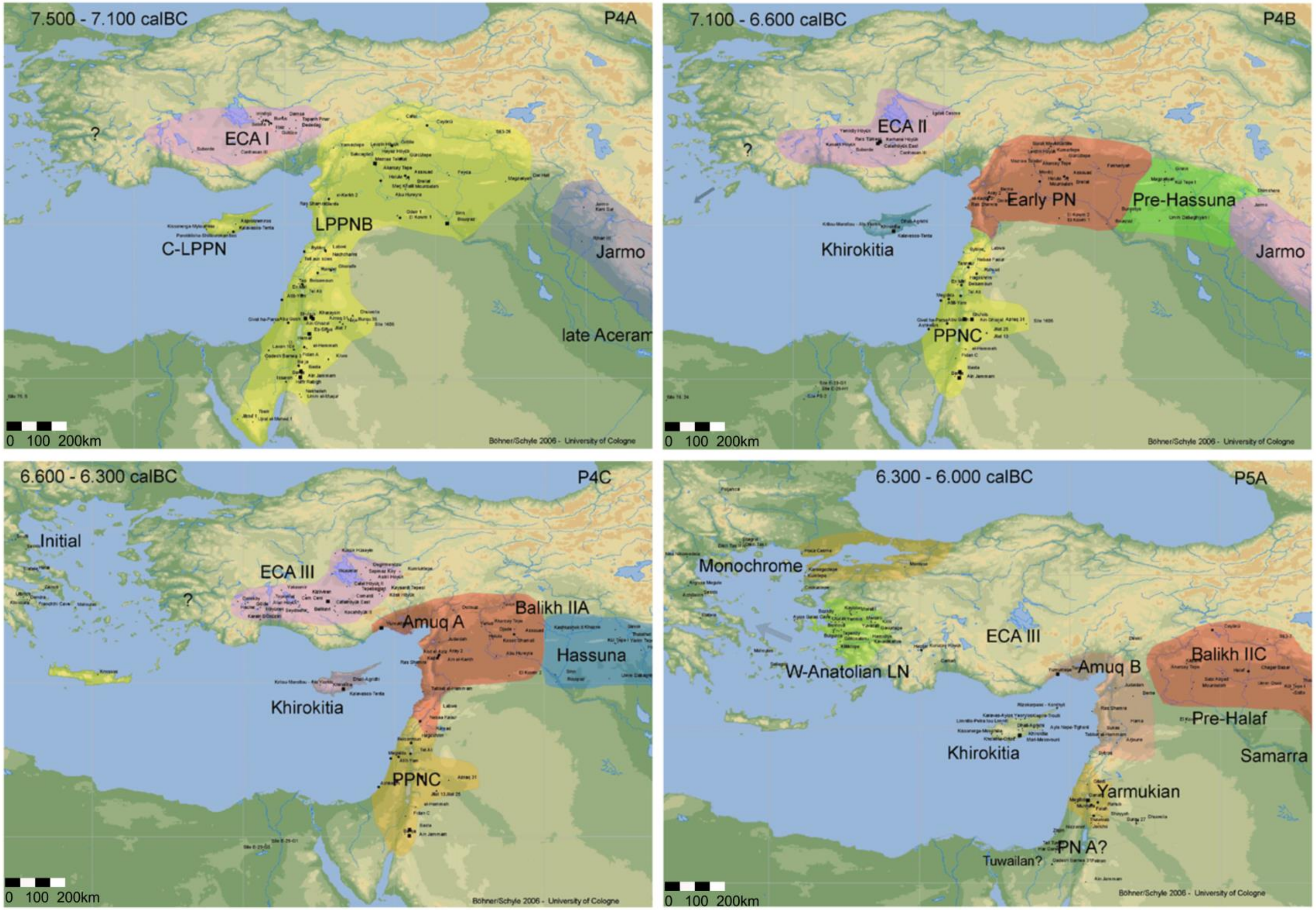


Figure 3.1c: Main cultural entities in Southwest Asia 7,500-6000 cal BC (source: radiocarbon CONTEXT database).

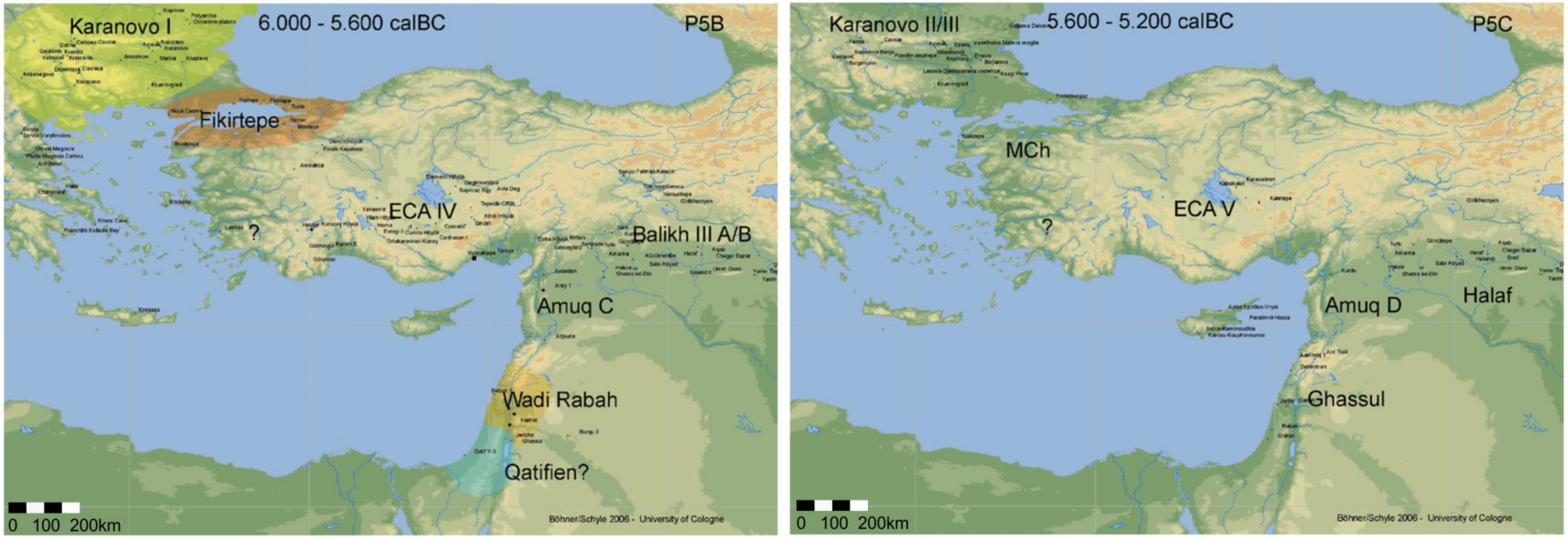


Figure 3.1d: Main cultural entities in Southwest Asia 6000-5200 cal BC (source: radiocarbon CONTEXT database).

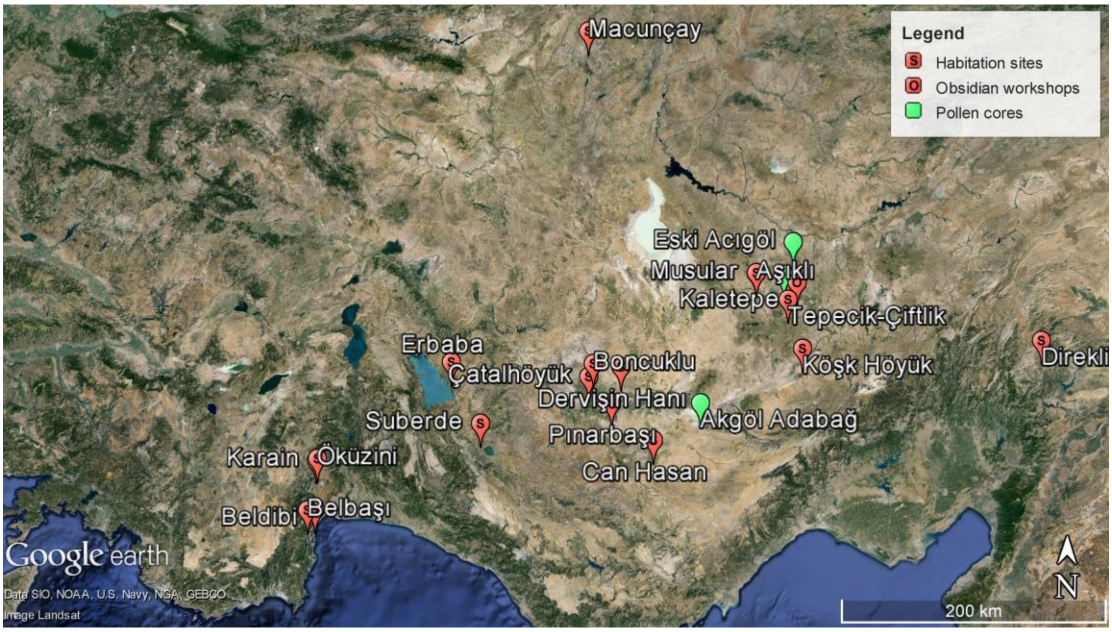


Figure 3.2: Map of the prehistoric sites in central Anatolia mentioned in the text.

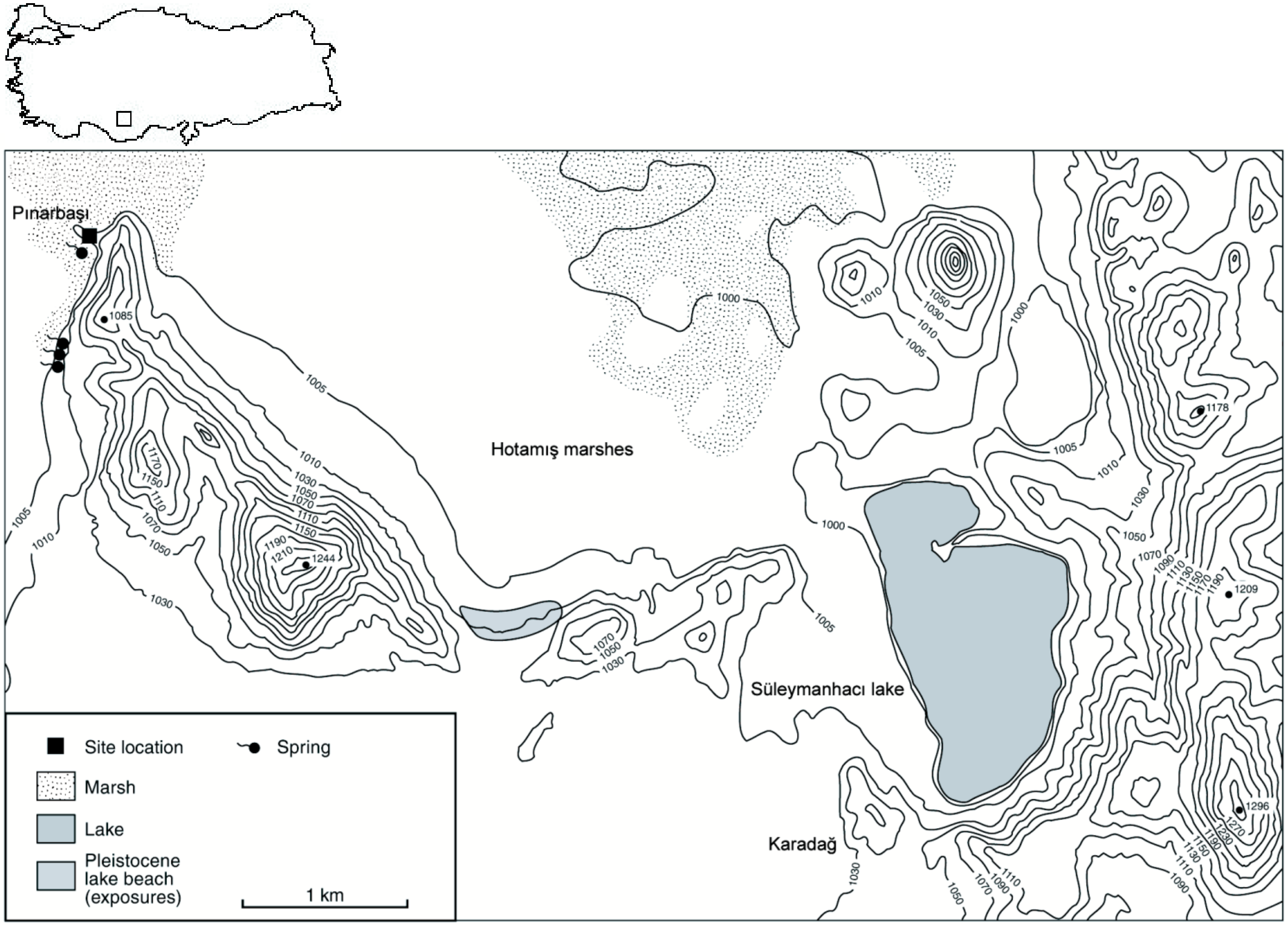


Figure: 3.3: Map showing the location of the Pınarbaşı rock-shelter and springs (after Asouti 2003a)

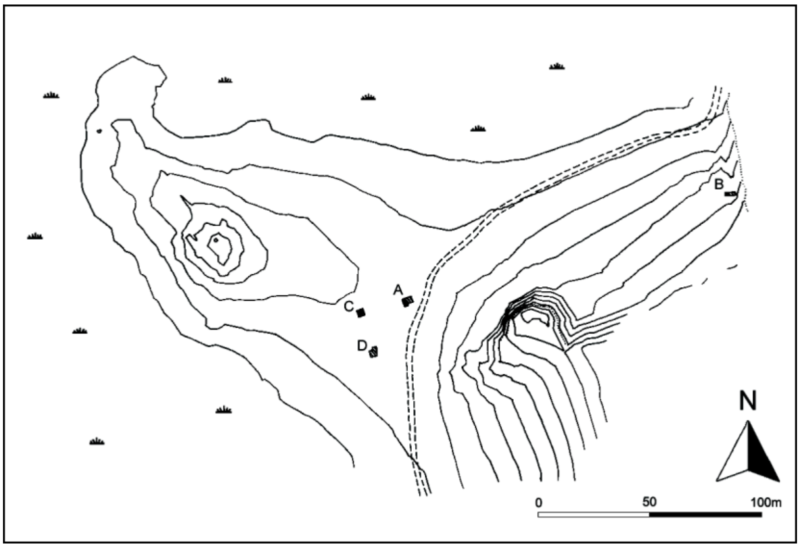


Figure 3.4: Map showing the location of the different excavation areas (A, B, C and D) at Pınarbaşı.

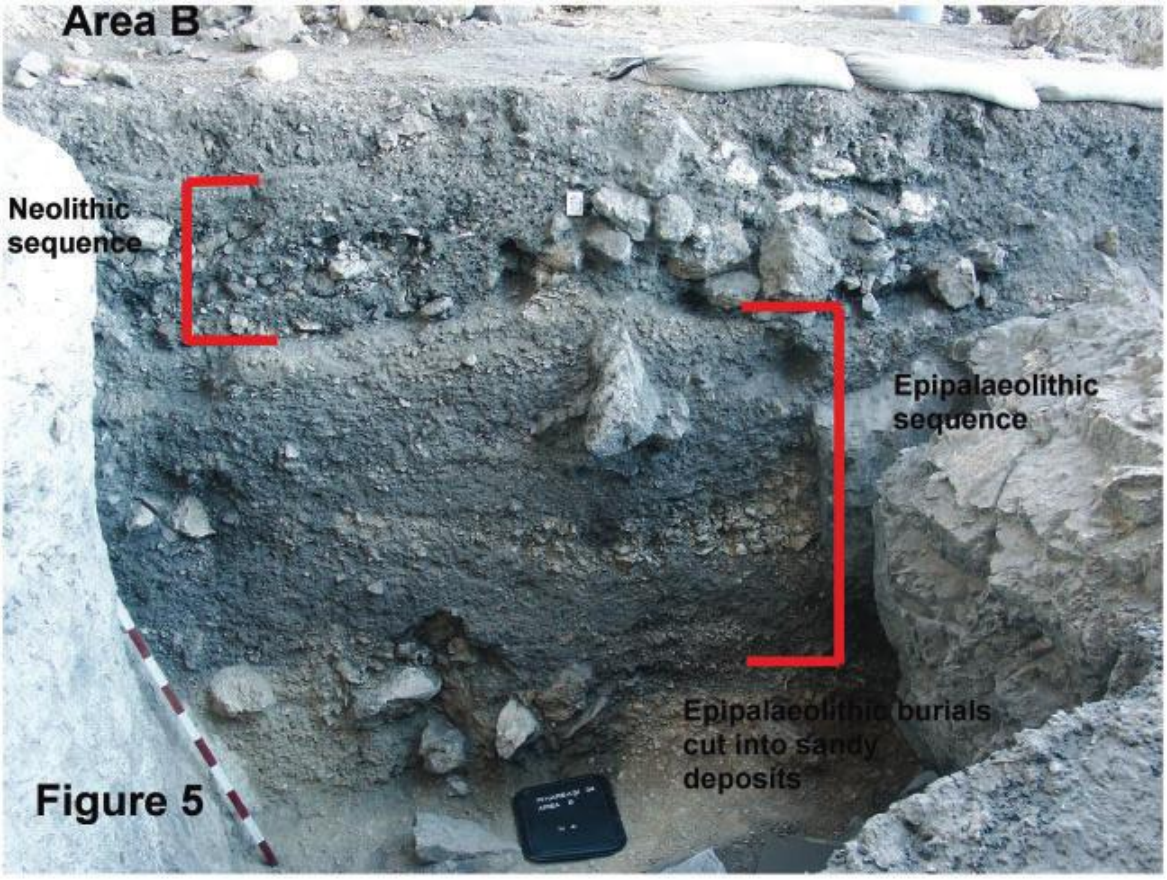


Figure 3.5: Epipalaeolithic and Neolithic stratified deposits excavated at Pınarbaşı Site B (after Baird et al. 2013).

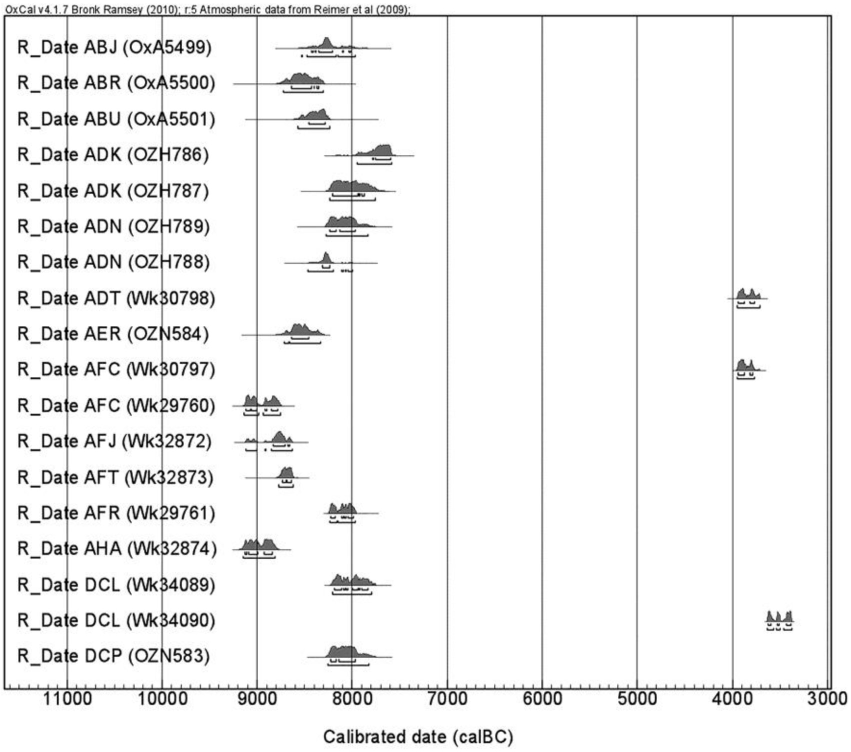


Figure 3.6: Radiocarbon dates from Pınarbaşı (after Fairbairn et al. 2014).

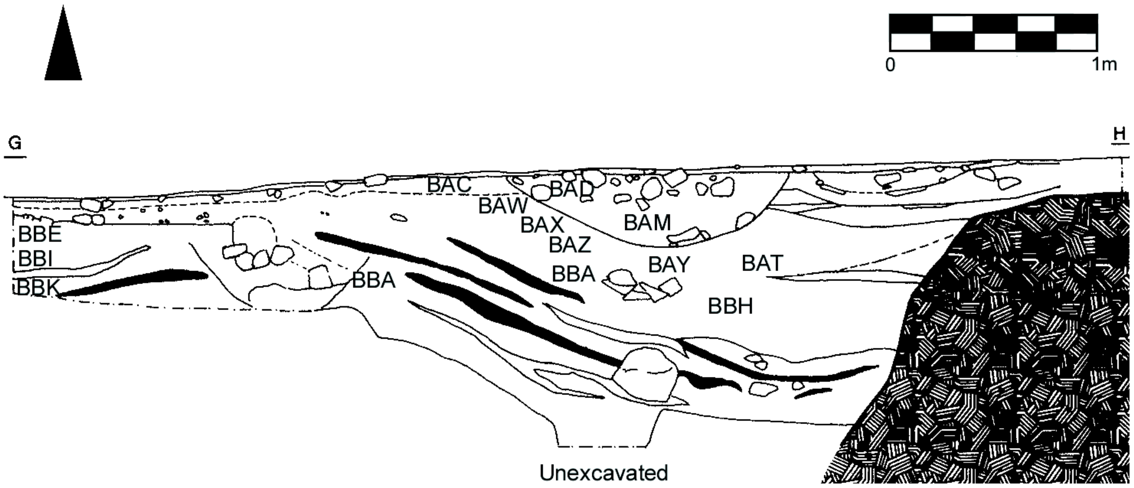


Figure 3.7: Section of Late Neolithic and Chalcolithic deposits excavated at Pınarbaşı Site B (after Asouti 2003a).

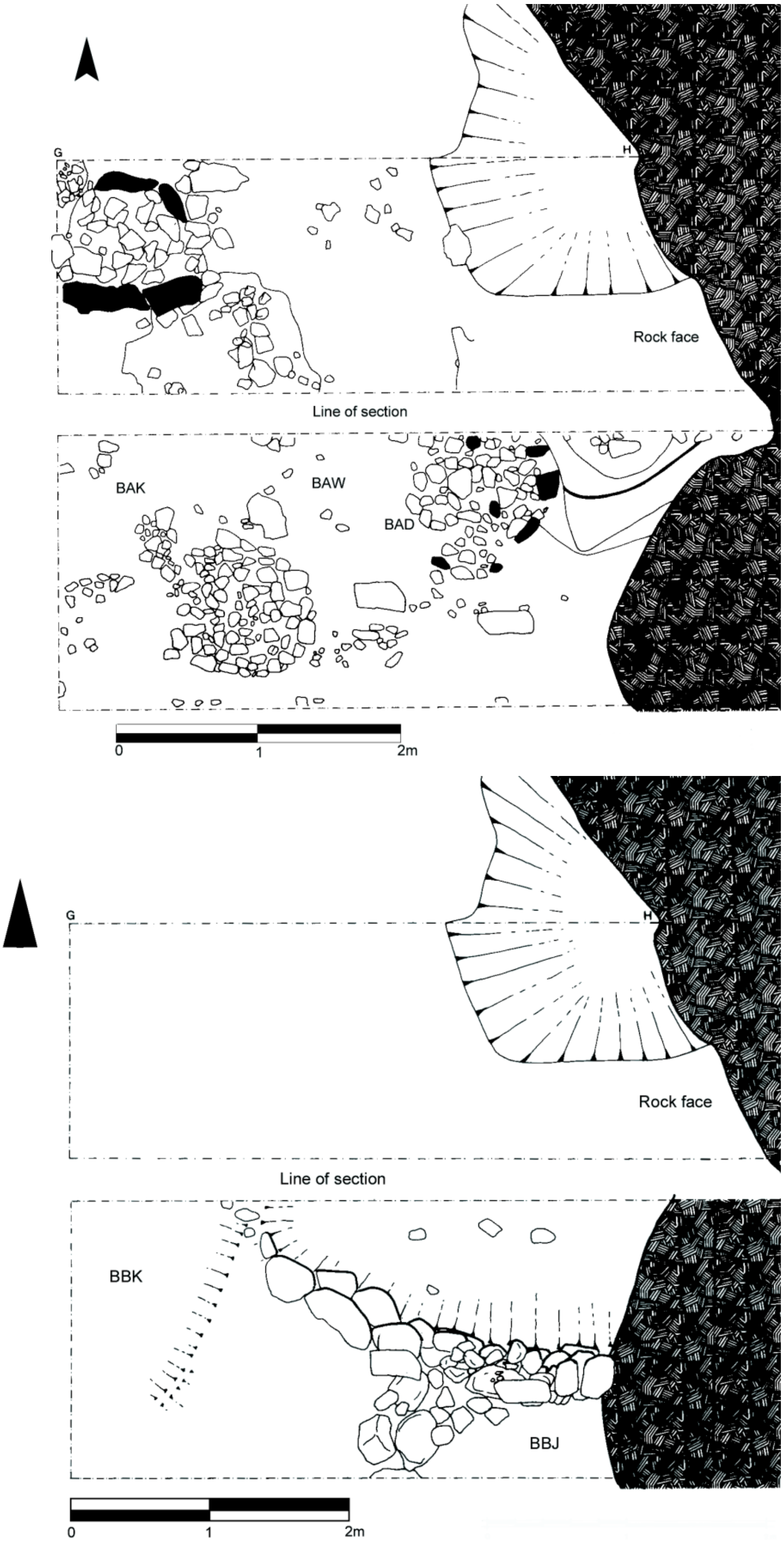


Figure 3.8: Plan of Late Neolithic and Chalcolithic deposits excavated at Pınarbaşı Site B (after Asouti 2003a).

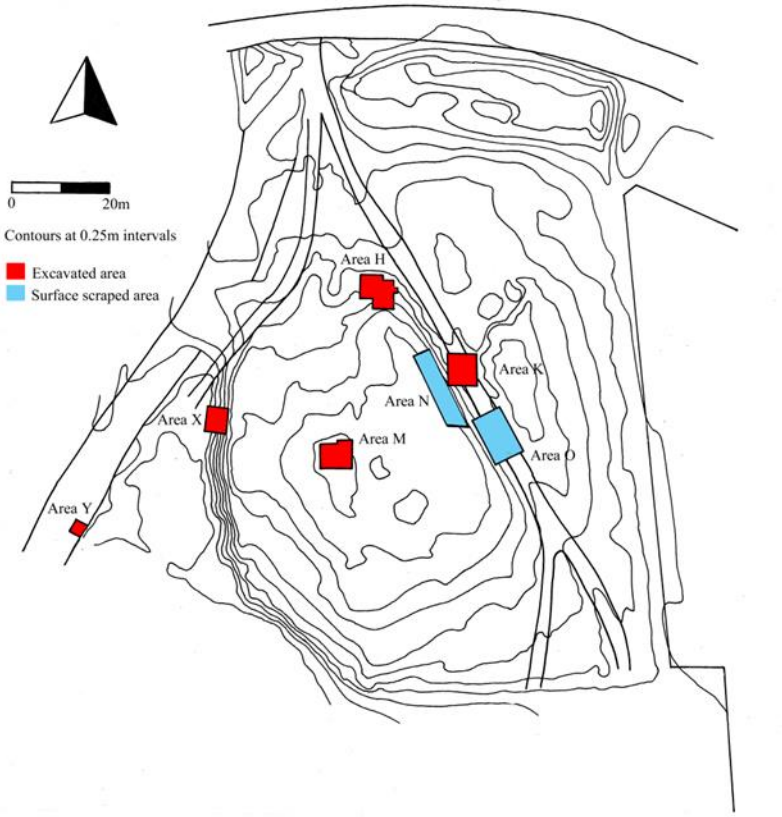


Figure 3.9: Map of excavated areas at Boncuklu.

Figure 3.10: Map showing the location of all the prehistoric sites in the Konya plain sampled by the present study.

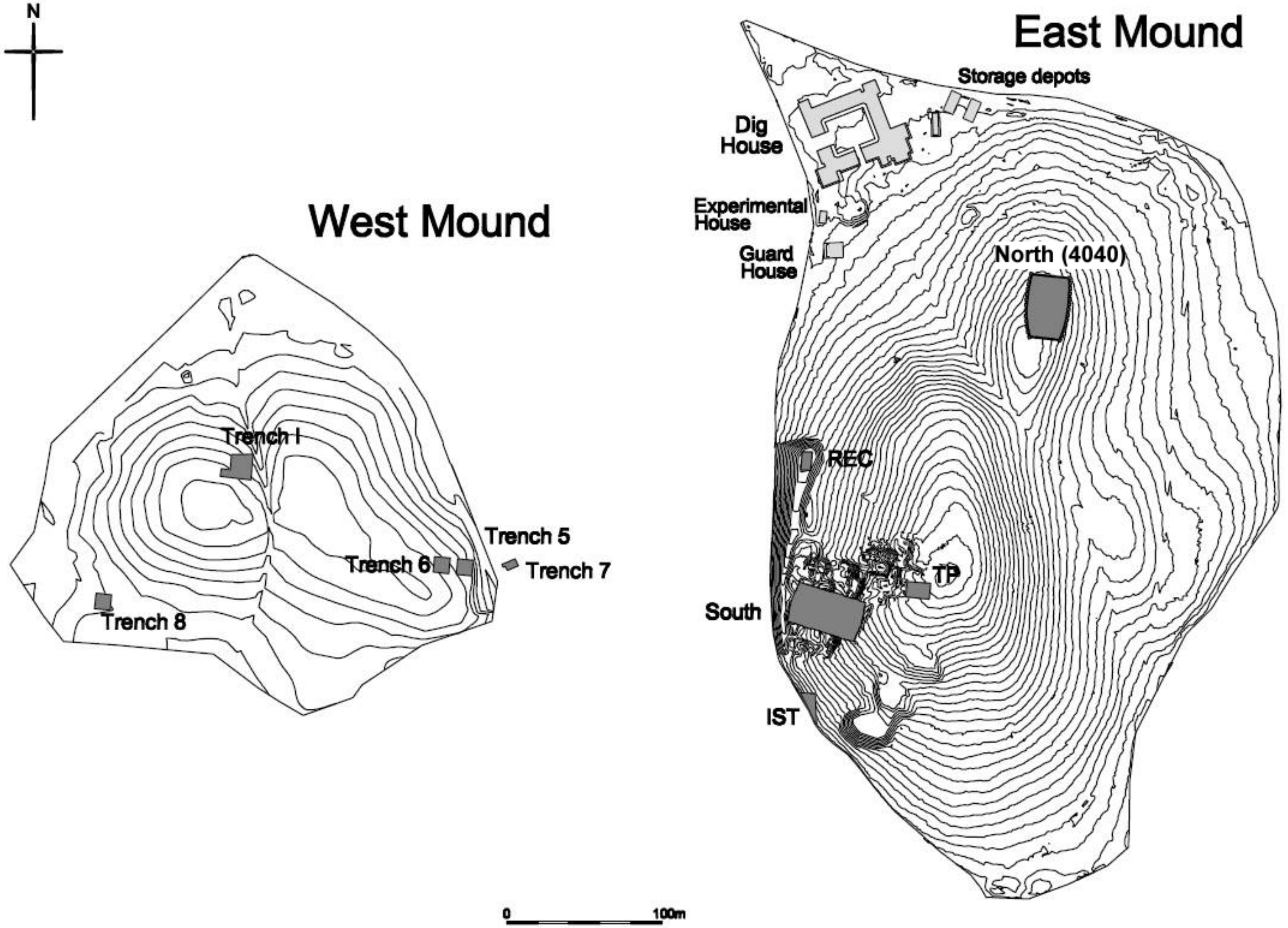


Figure 3.11: Map of the Çatalhöyük East and West mounds, showing the location of all excavated areas.

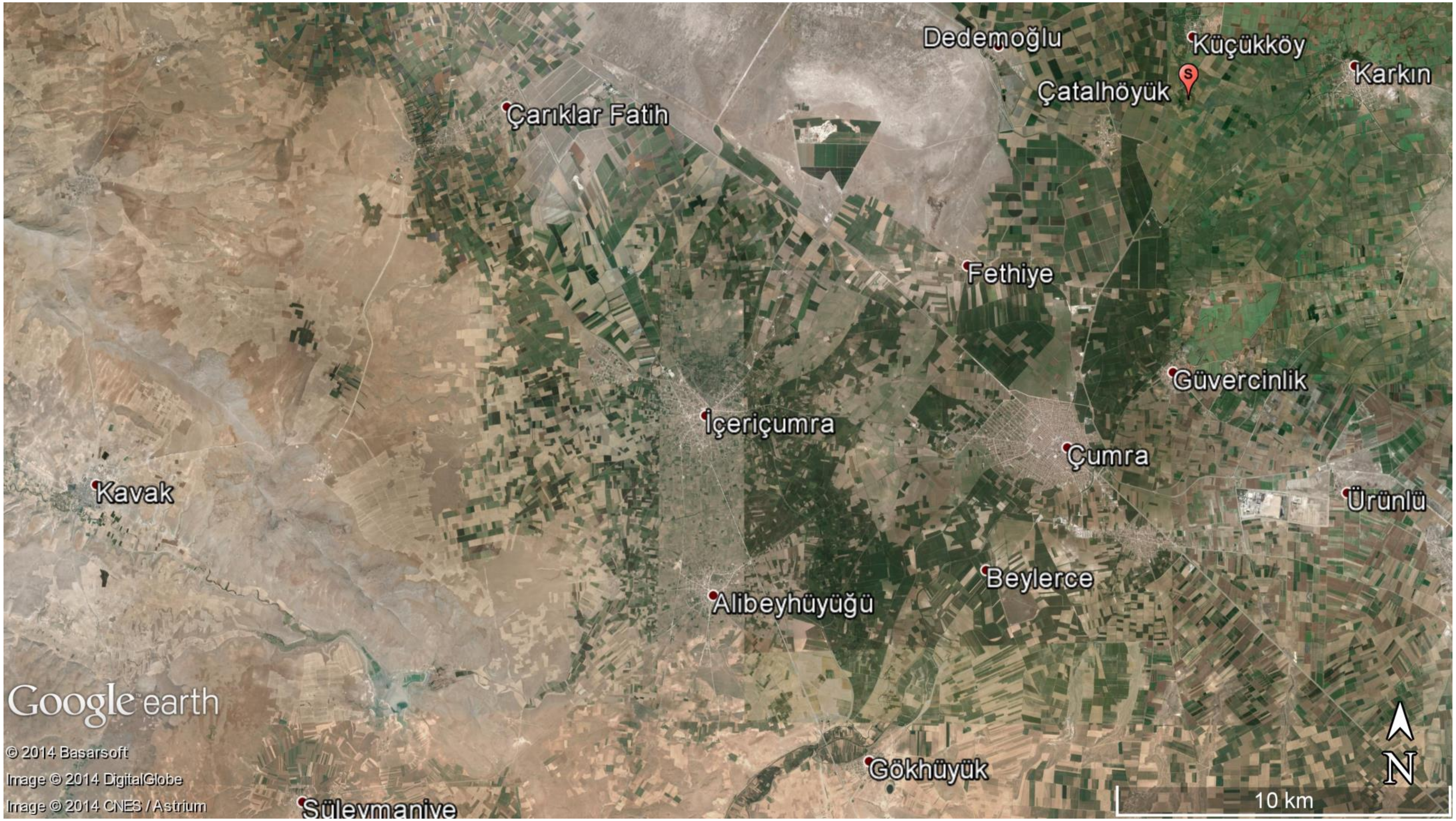


Figure 3.12: Map showing the location of Çatalhöyük on the Çarşamba alluvial fan in relation to the proximate Çarşamba catchment on the Taurus foothill zone to the south.

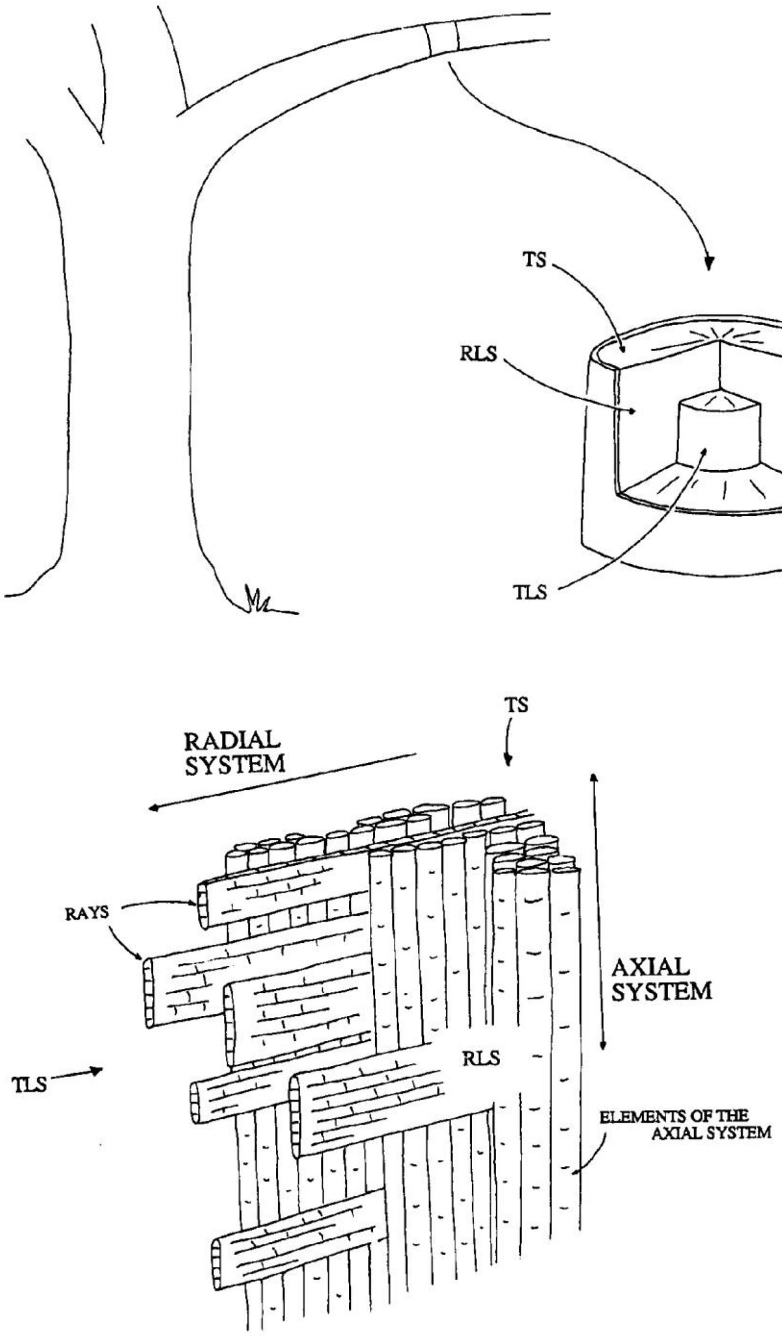


Figure 4.1: Graphical representation of the positioning and direction of the three anatomical planes (TS: Transverse Section; RLS: Radial Longitudinal Section; TLS: Tangential Longitudinal Section) in secondary xylem (wood) stems (after Hather 2000).

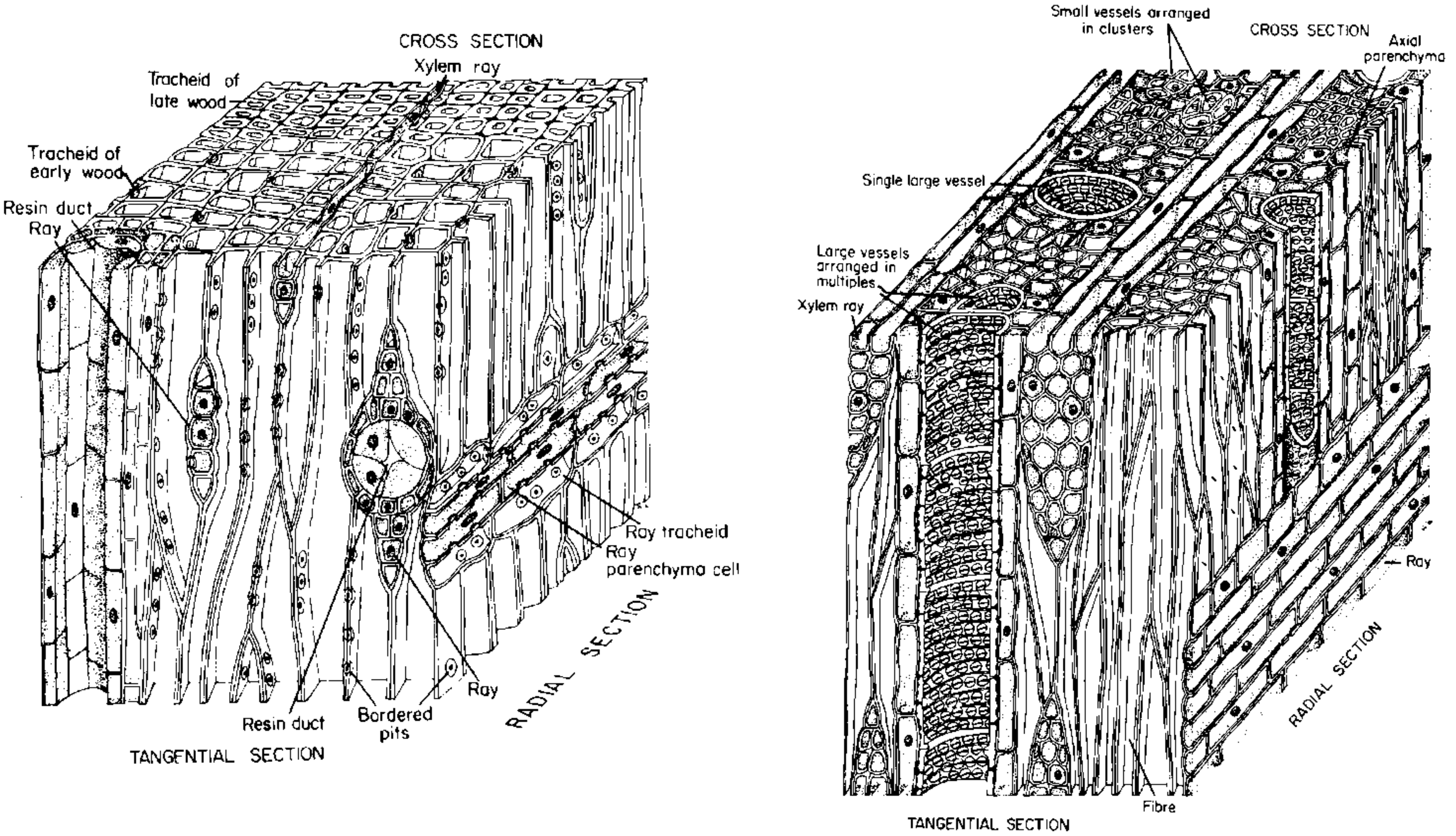


Figure 4.2: Three-dimensional representation of the anatomical planes and key anatomical features of gymnosperms (conifers, also known as softwoods) (left) and dicotyledonous woods (also known as hardwoods) (right) (after Fahn 1990).

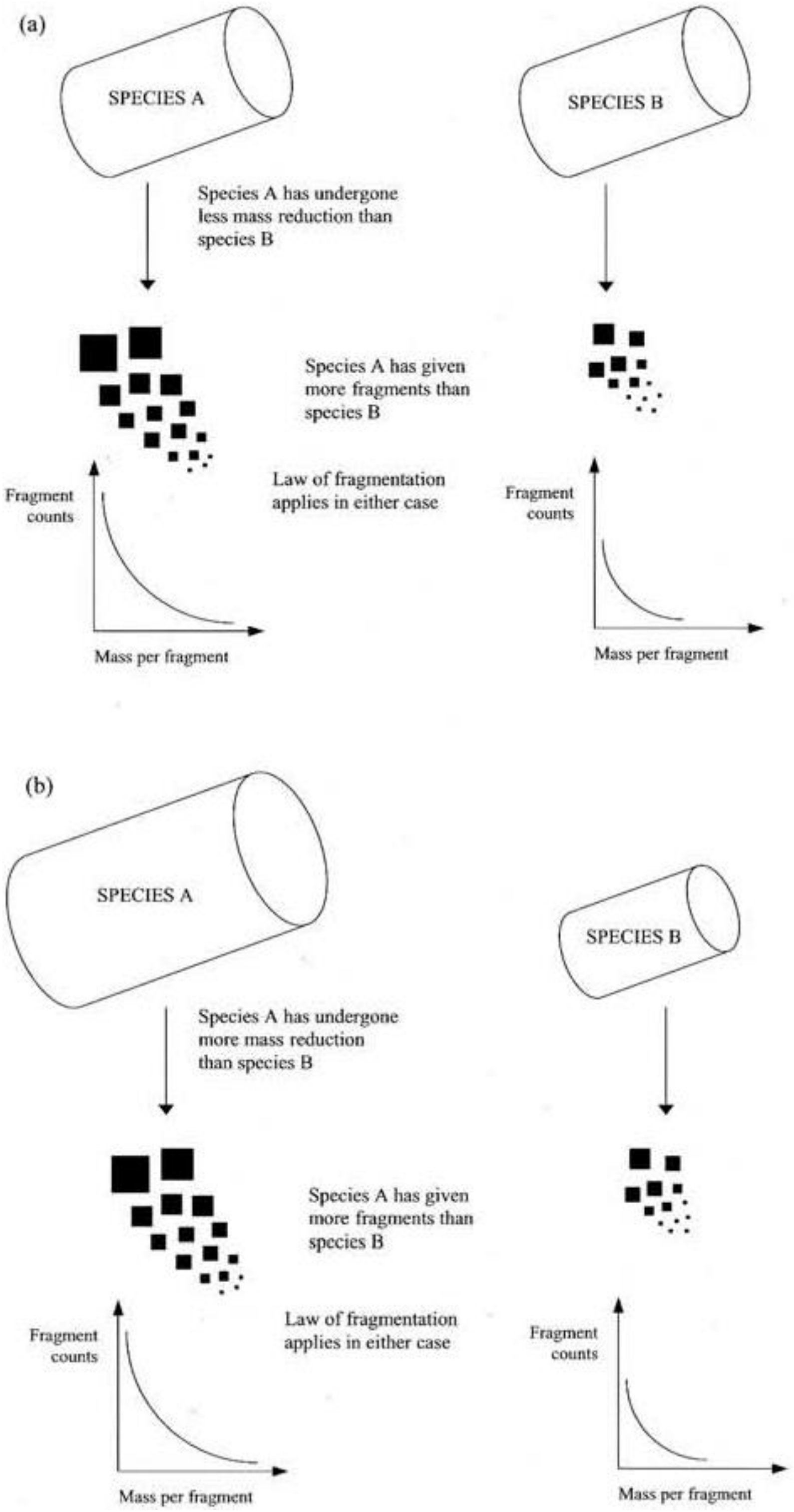


Figure 4.3: Visualisation of Chabal's Law of Fragmentation (after Asouti and Austin 2005).

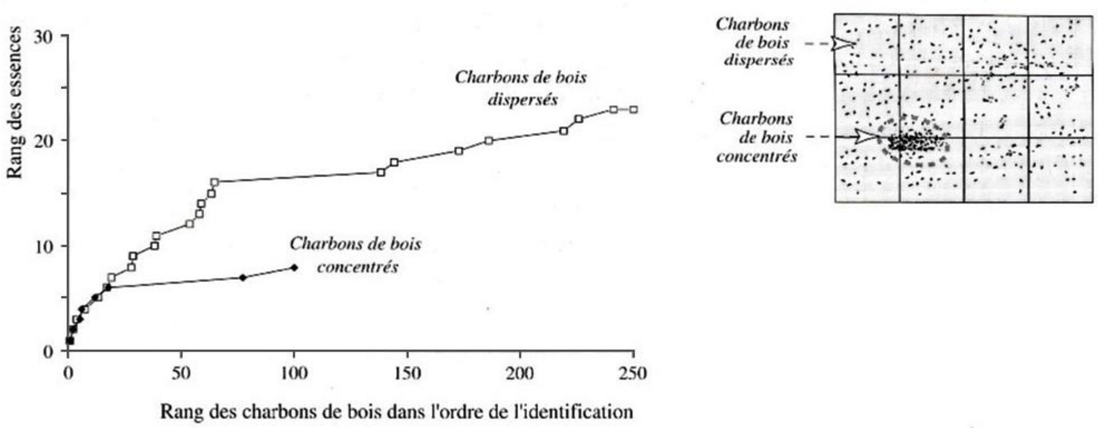


Figure 4.4: Predicted sub-sampling levels (fragment counts) for charcoal samples derived from dispersed and primary fuel waste contexts using saturation curves (modified after Chabal et al. 1999).

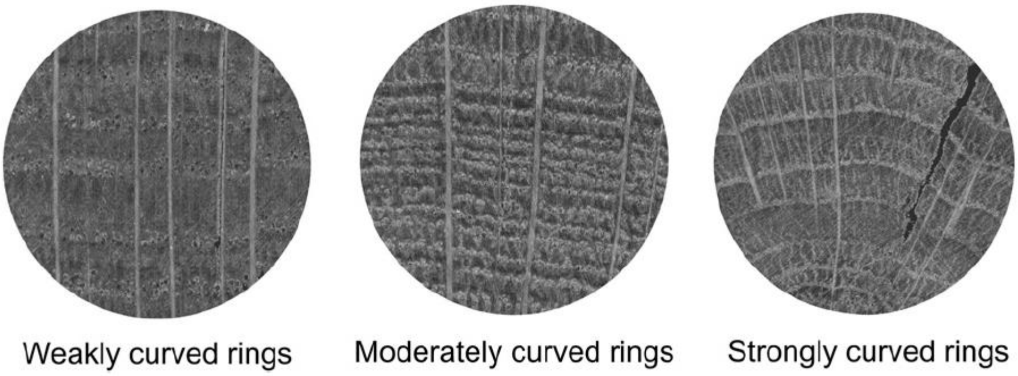


Figure 4.5: Test card for qualitative evaluation of tree-ring curvature degree (after Marguerie and Hunot 2007).

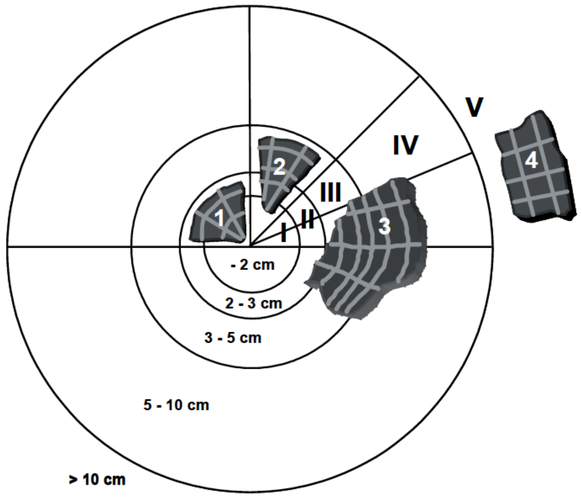


Figure 5. Diameter template, diameter size-classes (I-V) and examples of charcoal fragments to be sized (1-4). Result of sizing: Fragment 1, class II; fragment 2, class III; fragment 3, class IV; fragment 4, class V.

Figure 4.6: Visualisation of the “circle tool” used for the estimation of wood diameter size classes represented in an anthracological assemblage (after Ludemann 2006).

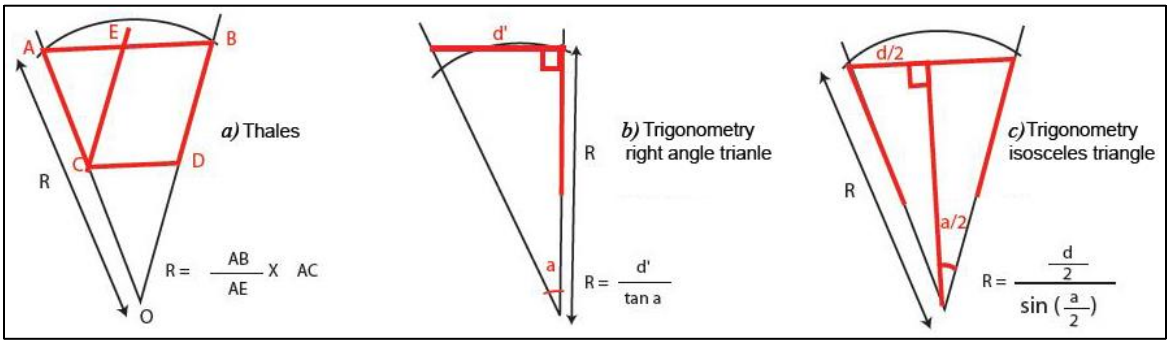
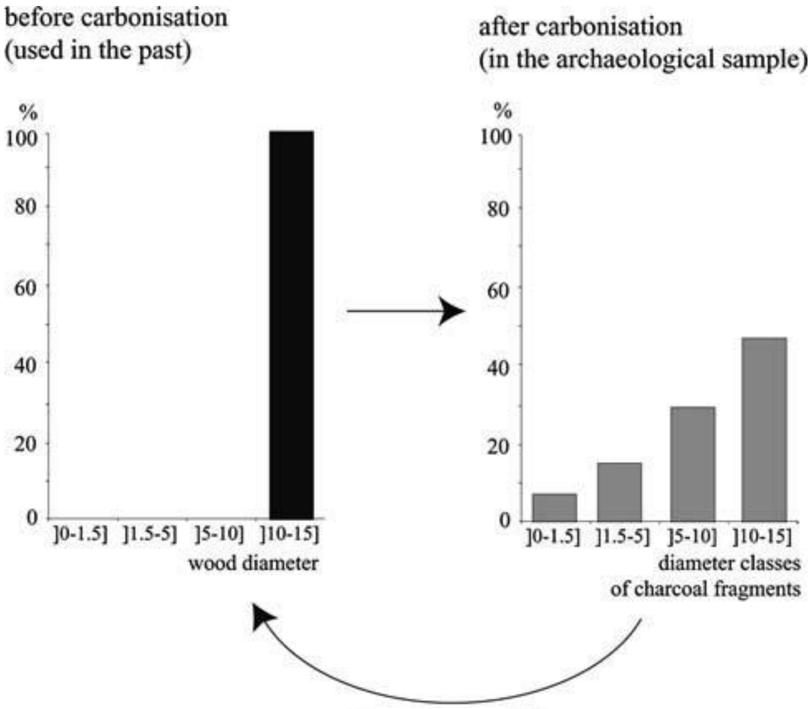


Figure 4.7: Visualisation of the trigonometric tool method of estimation of the radius of wood curvature (after Paradis et al. 2013).



Theoretical model

Figure 4.8: Theoretical distribution of diameter size classes in fuel waste debris. A log 10-15cm in diameter is predicted to produce a low number of small diameter fragments and a high number of large diameter fragments (skewed to the right) (after Dufraisse 2008).

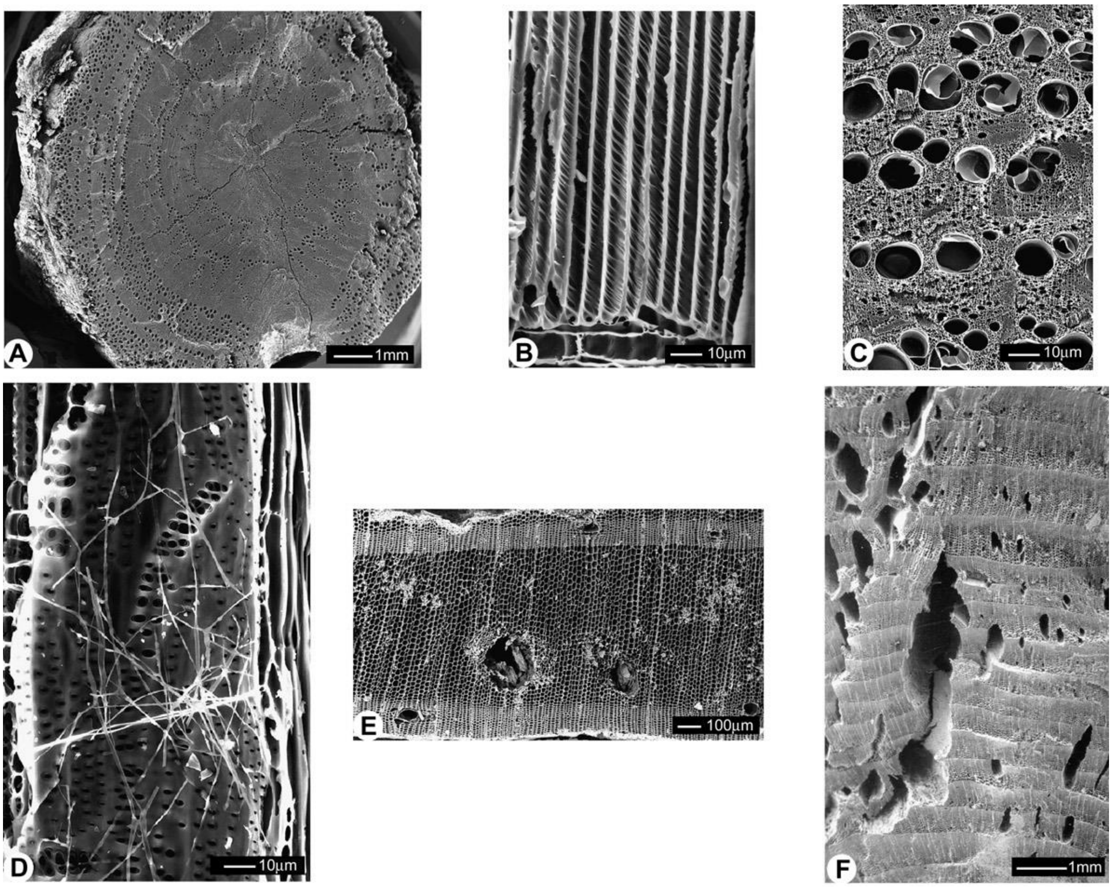


Figure 4.9: Scanning electron micrographs showing qualitative dendrological features in charred wood specimens (after Marguerie and Hunot 2007).

(A) *Quercus* sp.: shoot with bark and pith.
(B) *Picea mariana*: reaction wood in tracheids.
(C) *Quercus* sp.: tyloses in vessels (pores).
(D) *Quercus* sp.: fungal hyphae inside vessels.
(E) *Pinus sylvestris*: insect boreholes.
(F) *Picea glauca*: radial cracks.

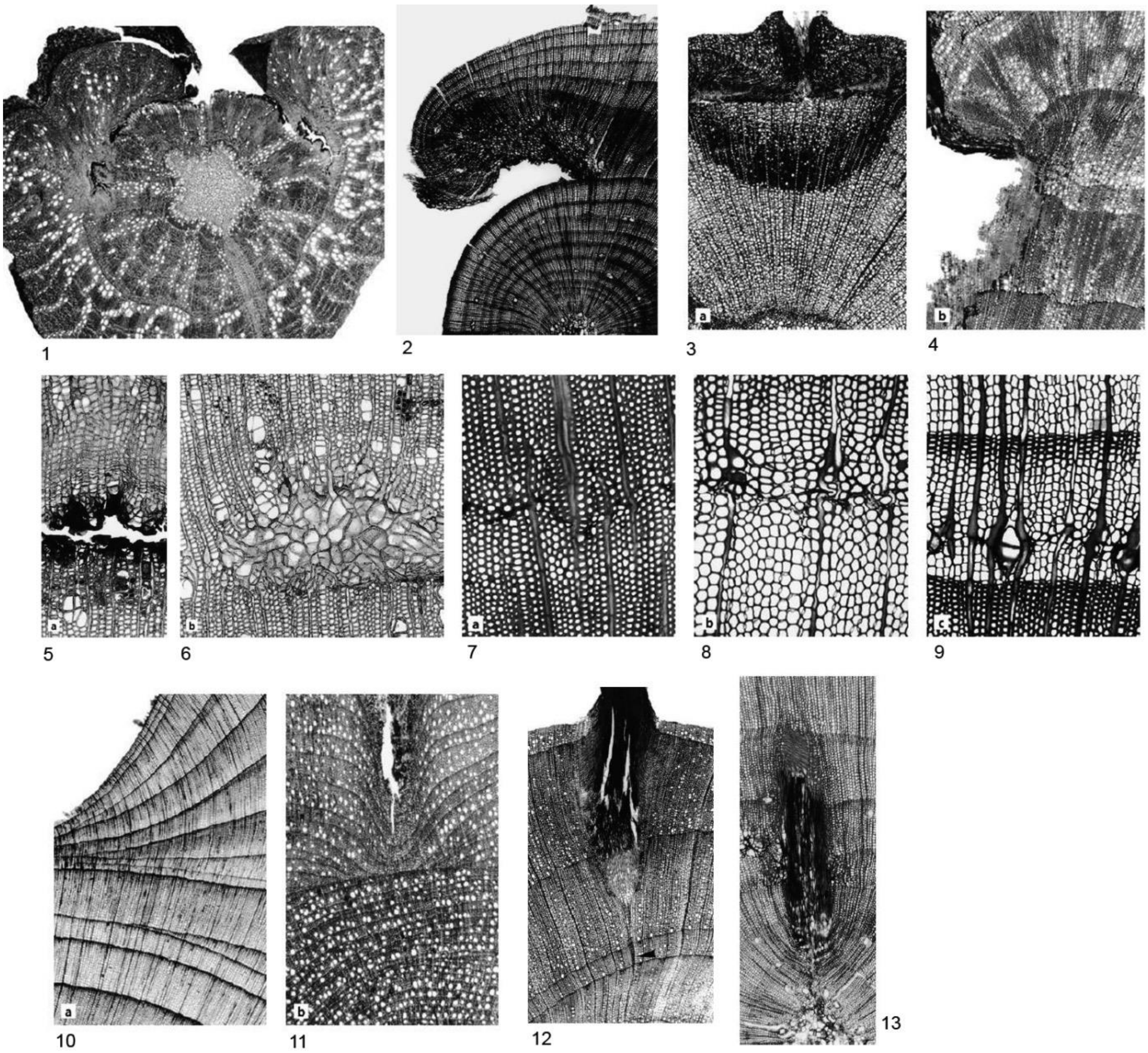
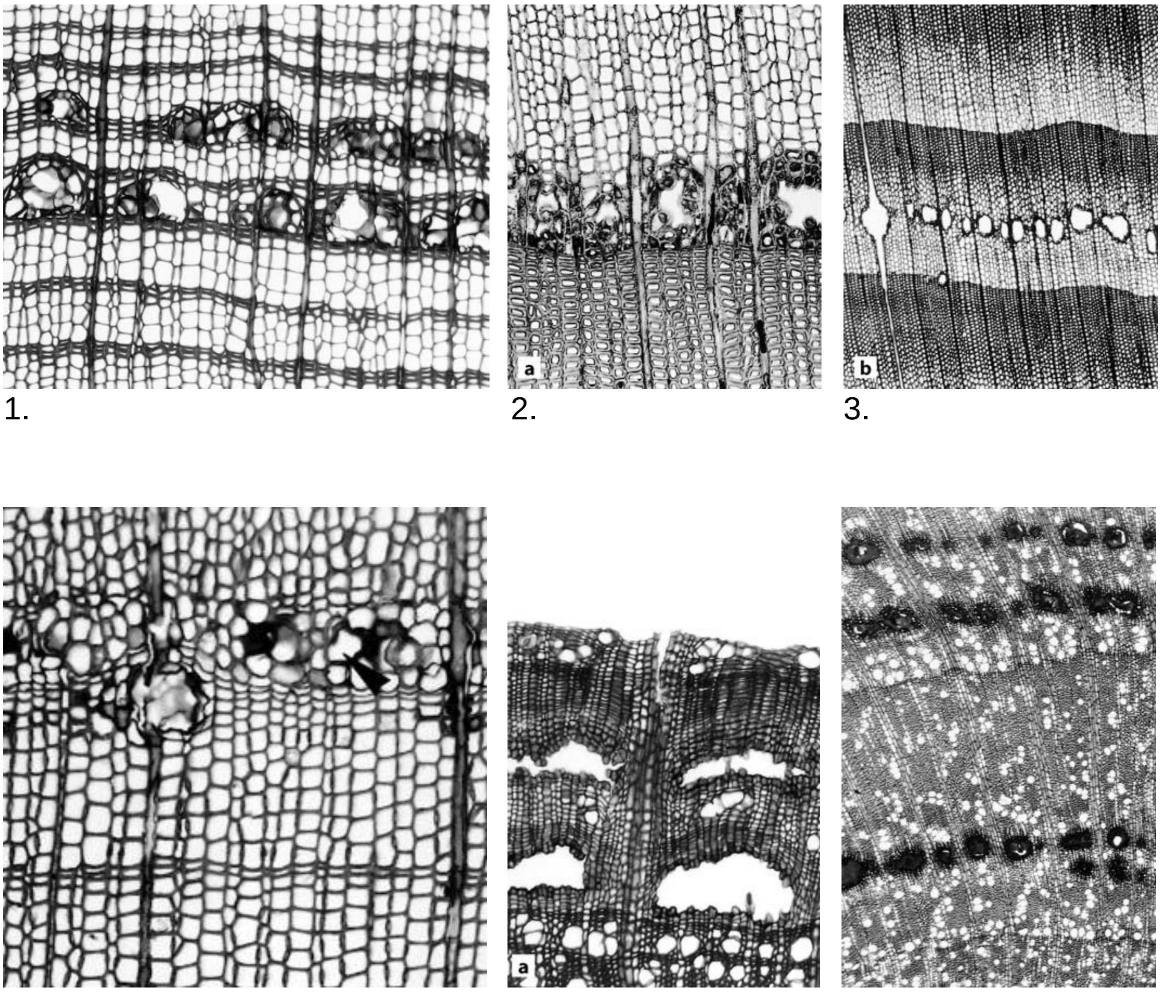


Figure 4.10: Examples of scar/callus tissue and radial overgrowth.

1. Quercus robur: Scar tissue and radial overgrowth formed in reaction to hail damage to the bark (after Schweingruber 2007: p.86, Fig. 5.3).
2. Pinus banksiana: Scar tissue and radial overgrowth formed in reaction to frost damage (after Schweingruber 2007: p.88, Fig. 5.6).
3. Rhododendron ferrugineum: Scar and callus tissue, and radial overgrowth formed in reaction to trauma (after Schweingruber 2007: p.193, Fig. 8.2).
4. Olearia phlogopapa: Scar and callus tissue formed in reaction to trauma (after Schweingruber 2007: p.193, Fig 8.2).
5. Alnus viridis: Scar tissue, formed as a reaction to insect infestation (after Schweingruber 2007: p.216, Fig. 8.67).
6. Alnus viridis: Callus tissue, formed as a reaction to pith fleck, caused by boring insect larvae (after Schweingruber 2007: p.216, Fig. 8.67)
7. Larix decidua: Discontinuous ring composed of thin-walled tracheids, caused by frost damage (after Schweingruber 2007: p.89, Fig. 5.9).
8. Larix decidua: Deformed and collapsed tracheids, and callus tissue, caused by frost damage, (after Schweingruber 2007: p.89, Fig. 5.9).
9. Larix decidua: Enlarged tracheids and bent rays, caused by frost damage (after Schweingruber 2007: p.89, Fig. 5.9).
10. Juniperus nana: Wedging, tissue re-orientation and callus formation caused by local trauma affecting cambium (after Schweingruber 2007: p.89, Fig. 5.9).
11. Erica carnea: Callus tissue and radial overgrowth resulting in tissue re-orientation (after Schweingruber 2007: p.89, Fig. 5.9).
12. Tilia cordata: Callus tissue formed around adventitious shoot (after Schweingruber 2007: p.84, Fig. 4.66).
13. Pinus sylvestris: Scar tissue, formed around needle trace (after Schweingruber 2007: p.69, Fig. 4.35).



1. 2. 3.

4. 5. 6.

Figure 4.11: Examples of traumatic resin canals and gum ducts.

1. *Larix dahurica*: Tangential rows of traumatic canals (after Schweingruber 2007: p.185; Fig. 8.11).
2. *Abies alba*: Row of possibly traumatic resin canals filled with phenolic substances (after Schweingruber 2007: p.184; Fig. 8.9a).
3. *Larix dahurica*: Row of traumatic resin canals in the middle of the growth ring (after Schweingruber 2007: p.184; Fig. 8.9b).
4. *Pinus sylvestris*: Callus tissue overlaying resin canal. The tangential row of anomalous cells is partly filled with resin; on one side (marked by black arrow) is a hollow spot that could be the initial point of a resin canal (after Schweingruber 2007: p.184; Fig. 8.10).
5. *Prunus avium*: Traumatic gum ducts in the callus margin of pollarded stem (after Schweingruber 2007: p.187; Fig. 8.17).
6. *Prunus mahaleb*: Tangential rows of traumatic gum ducts in stem infested with a mucus-secreting fungus (after Schweingruber 2007: p.187; Fig. 8.16).

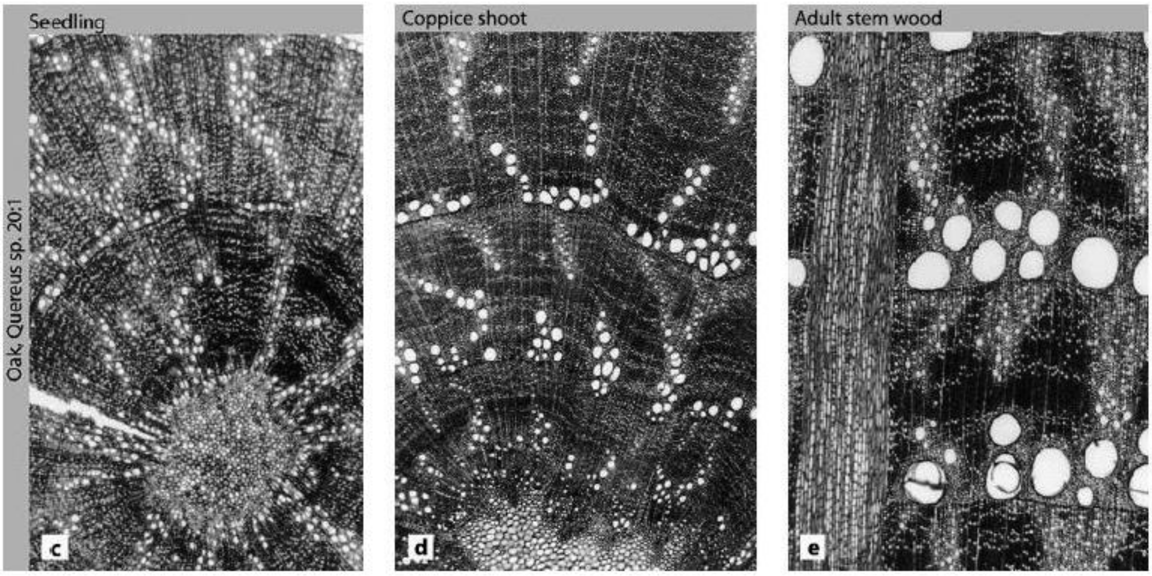


Figure 4.12: Anatomical variability in deciduous *Quercus.*

Left: Seedling – wood ring to semi-ring porous; pore diameter small.
Middle: Coppice stool shoot – wood ring porous; pore diameter medium to large.
Right: Adult stem wood – wood ring porous; pore diameter large.
(Modified after Schweingruber 2007: p.54, Fig. 4.11).

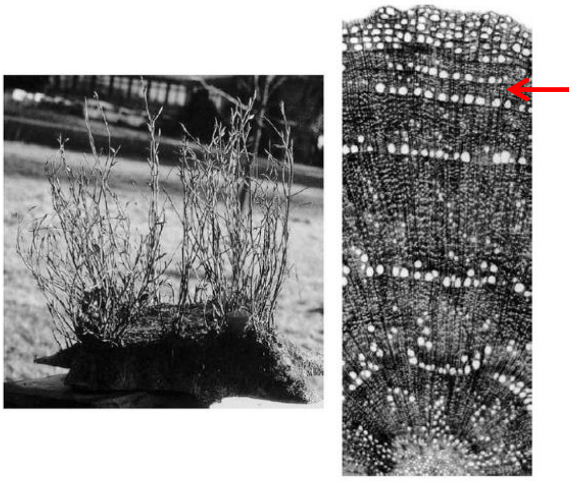


Figure 4.13a

Left: *Fagus sylvatica* coppice stool with new shoots (modified after, Schweingruber 2007: p.162, Fig. 7.58).

Right: *Castanea sativa* coppice shoot, developed after stand felling. In the first 4 years improved growth rates reflect reduced competition. Reduction in growth (marked by red arrow) represents increasing competition for light as the canopy develops (modified after, Schweingruber 2007: p.115, Fig. 5.49).

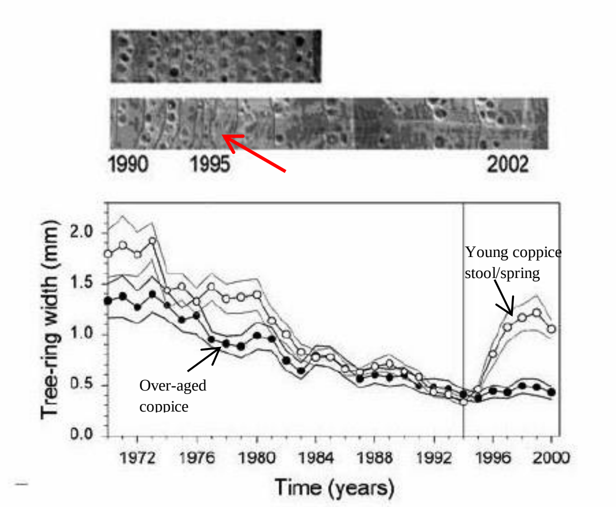


Figure 4.13b

Effects of thinning on growth ring development in a coppiced stand of managed *Quercus pyrenaica* woodland (NE Spain). In the year after thinning (1995) growth ring width of young coppice stools was dramatically increased (modified after Corcuera et al. 2006: p.95, Fig. 4a).

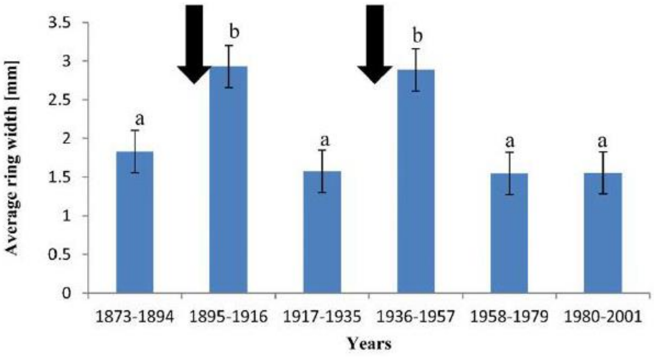


Figure 4.13c

Average ring width values in a coppice with oak standards show significantly improved average ring width for oak standards in the years following coppice felling cycles (indicated by black arrows). (modified after Altman et al. 2013: p.6, Fig. 5).

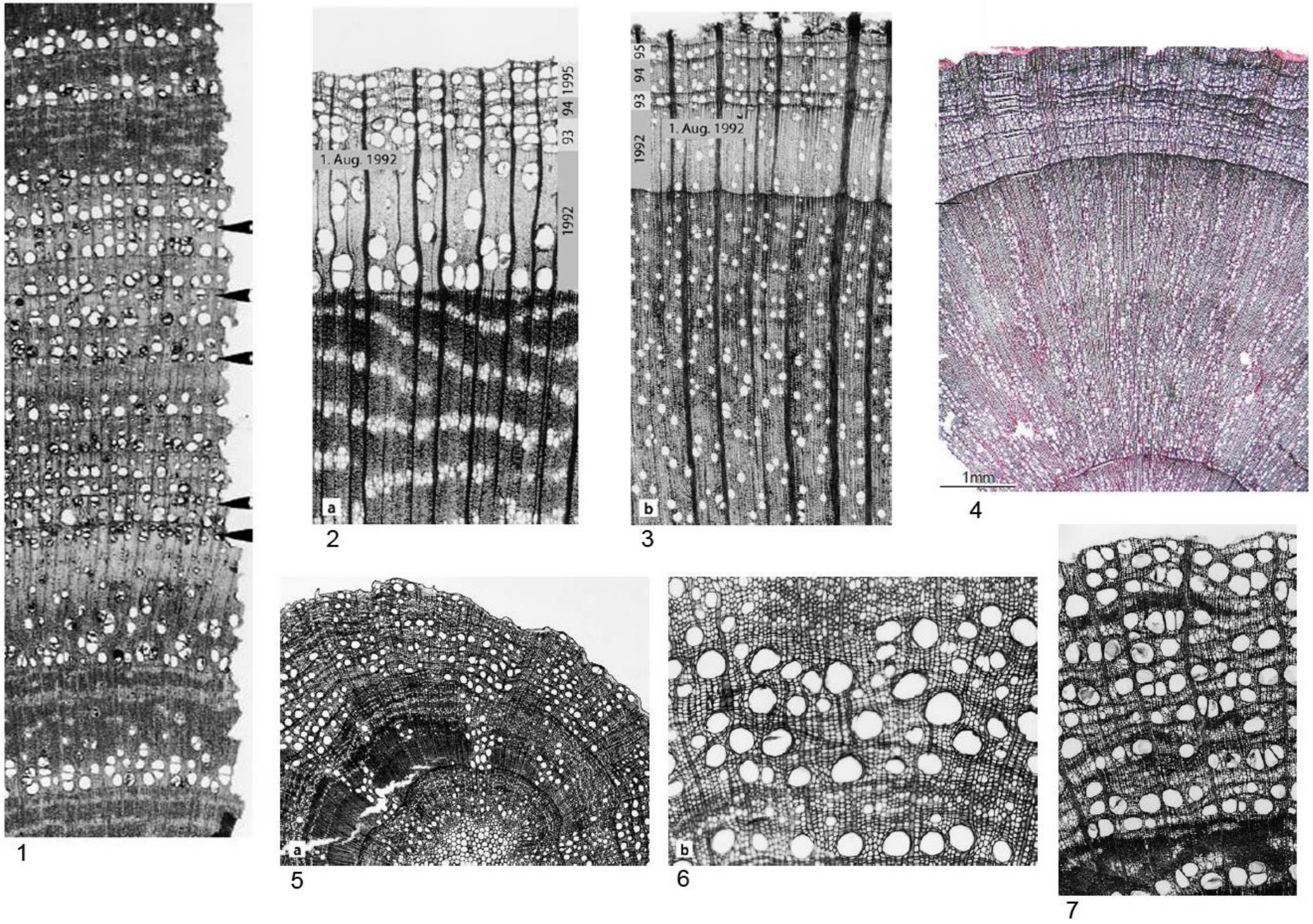


Figure 4.14: Growth rate reduction caused by cutting and herbivore browsing impacts.

1. *Fraxinus excelsior*: Episodes of growth reduction, indicated by successive narrow growth rings (marked by black arrows) of stem wood, caused by lopping and the loss of tree crown (Schweingruber 2007: p.166, Fig 7.65).
2. *Ulmus glabra*: Successive narrow rings following normal growth rings of stem wood, caused by pollarding (after Schweingruber 2007: p.160, Fig. 7.53a).
3. *Acer pseudoplatanus*: Successive narrow rings following normal growth rings of stem wood, caused by pollarding (after Schweingruber 2007: p.160, Fig. 7.53b).
4. *Corylus avellana*: Successive narrow rings following normal growth rings of hedgerow round wood, caused by pruning (after Schweingruber et al. 2008: p.167, Fig. 10.60).
5 & 6. *Quercus pubescens*: Very narrow growth rings, and discontinuous (false) rings of short shoot, caused by herbivore browsing (after Schweingruber 2007: p.175, Fig. 7.92).
7. *Ulmus glabra*: Very narrow growth rings, and discontinuous (false) rings of stunted, dwarf shrub, caused by herbivore browsing (after Schweingruber 2007: p.174, Fig. 7.89).

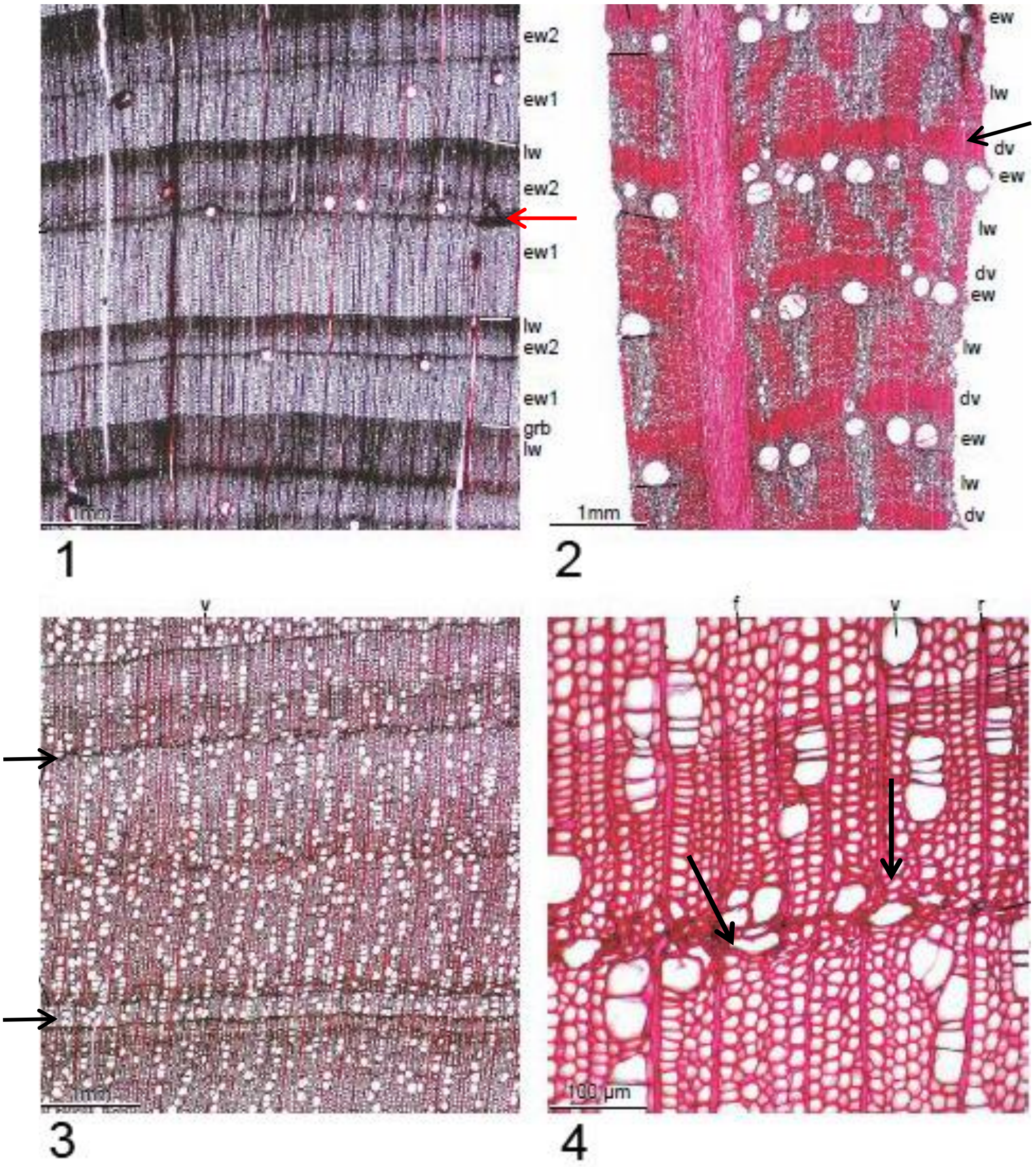


Figure 4.15: Effects of drought stress on growth ring development.

1. *Pinus leiophylla*: Early summer drought resulting in a brief period of growth reduction in the early wood (ew) portion of the growth ring (marked by the red arrow in the upper part of ew1); this was followed by increased rainfall in late summer creating another band of early wood growth (ew2) (after Schweingruber et al. 2008: p.158, Fig. 10.22).
2. *Quercus pubescens*: Summer aridity resulting in the formation of dense tangentially oriented fibre bands in early wood (after Schweingruber et al. 2008: p.158, Fig. 10.23).
3. *Alnus incana* growing in a periodically dry riverbed: irregularities in early wood and late wood (after Schweingruber et al. 2008: p.158, Fig. 10.24).
4. *Alnus incana*: Collapsed fibres and vessels (pores) resulting from drought stress (after Schweingruber et al. 2008: p.158, Fig. 10.24).

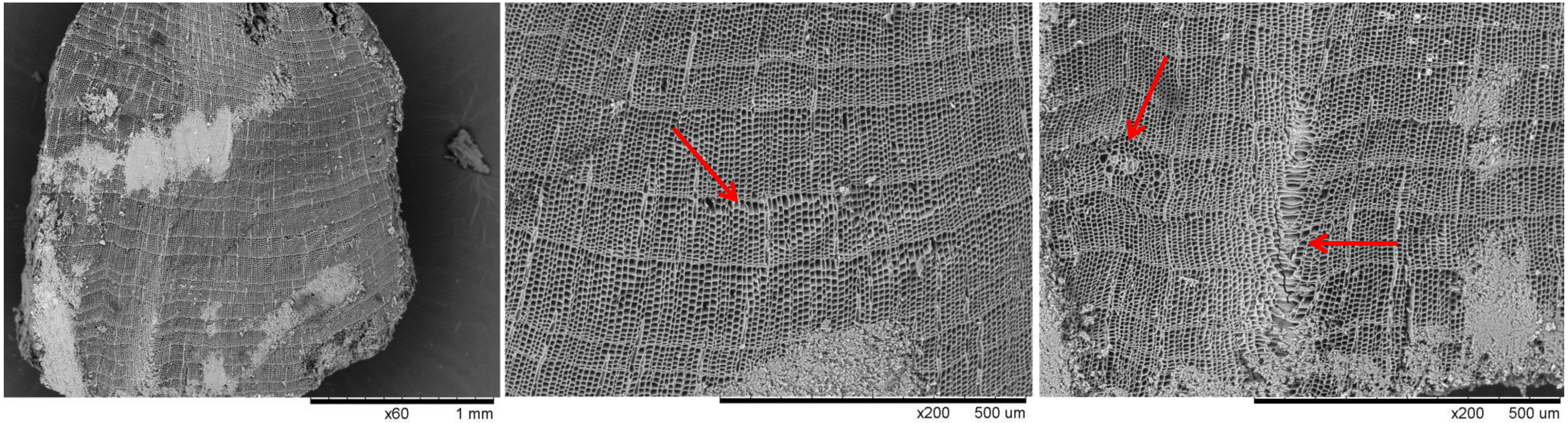


Figure 5.1: *Juniperus* (Pınarbaşı Epipaleolithic) showing irregular growth rings (left), deformed tracheids (middle and right), and growth over needle trace

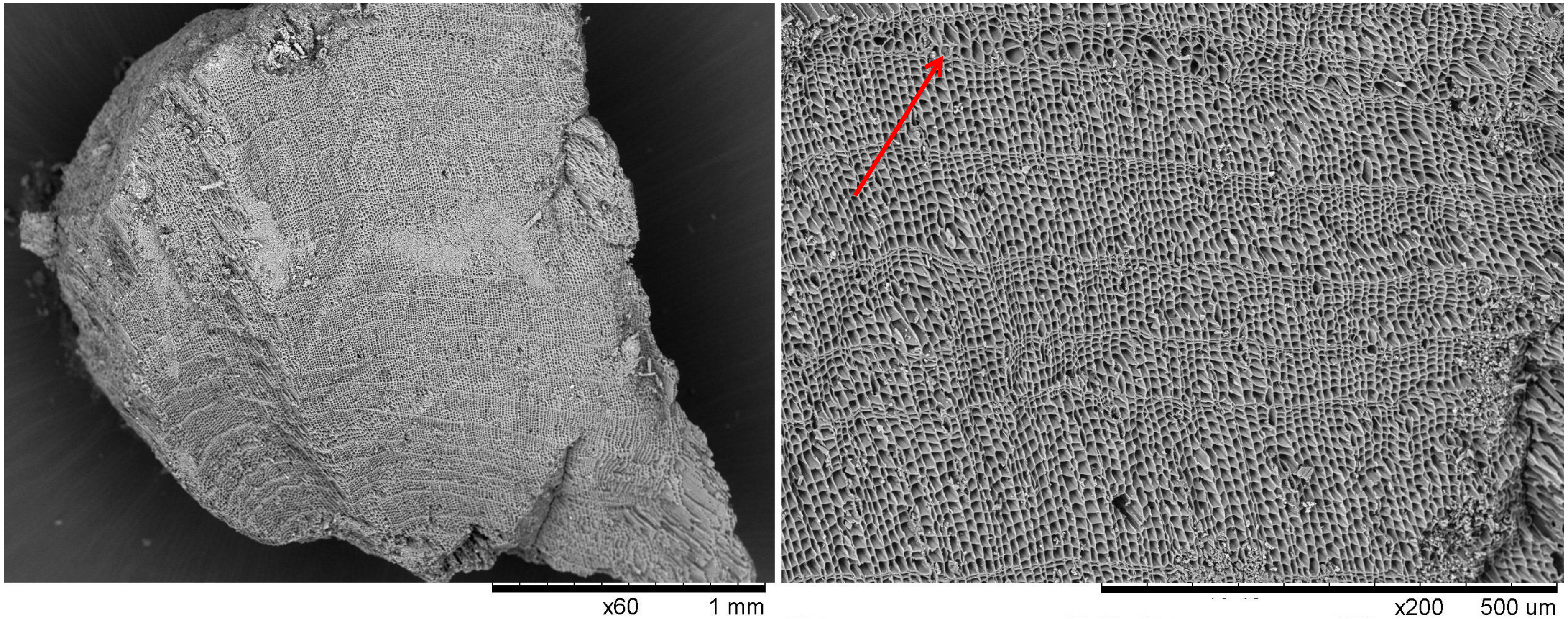


Figure 5.2: *Juniperus* (Pınarbaşı Epipaleolithic), narrow and discontinuous growth rings, deformed tracheids (right).

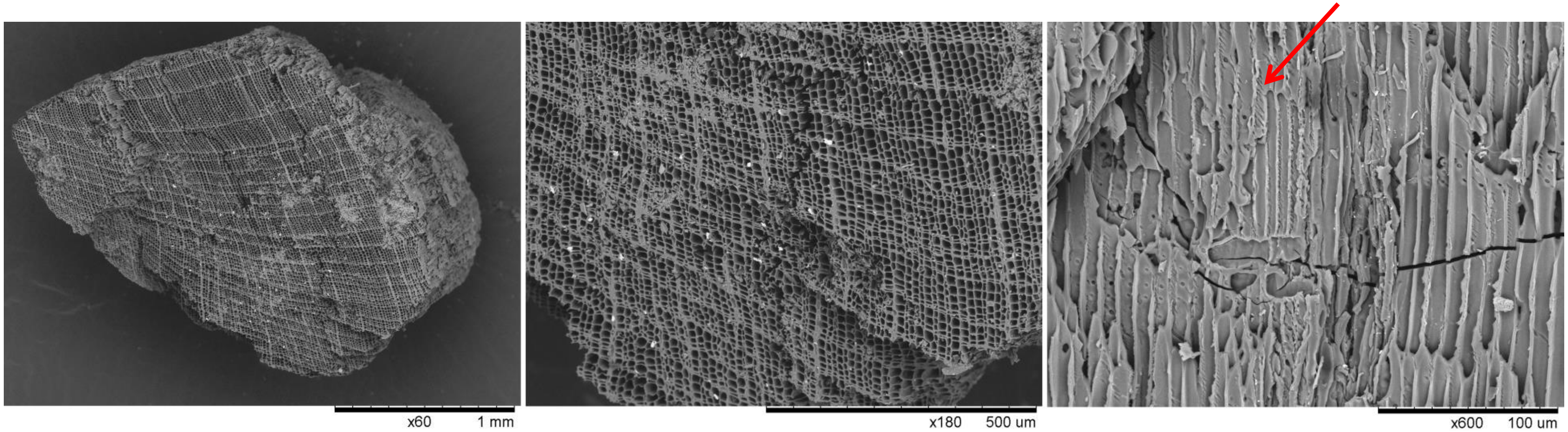


Figure 5.3: *Juniperus* (Pınarbaşı Epipalaeolithic), narrow and discontinuous growth rings, eccentric growth (left, middle), tension wood (right)

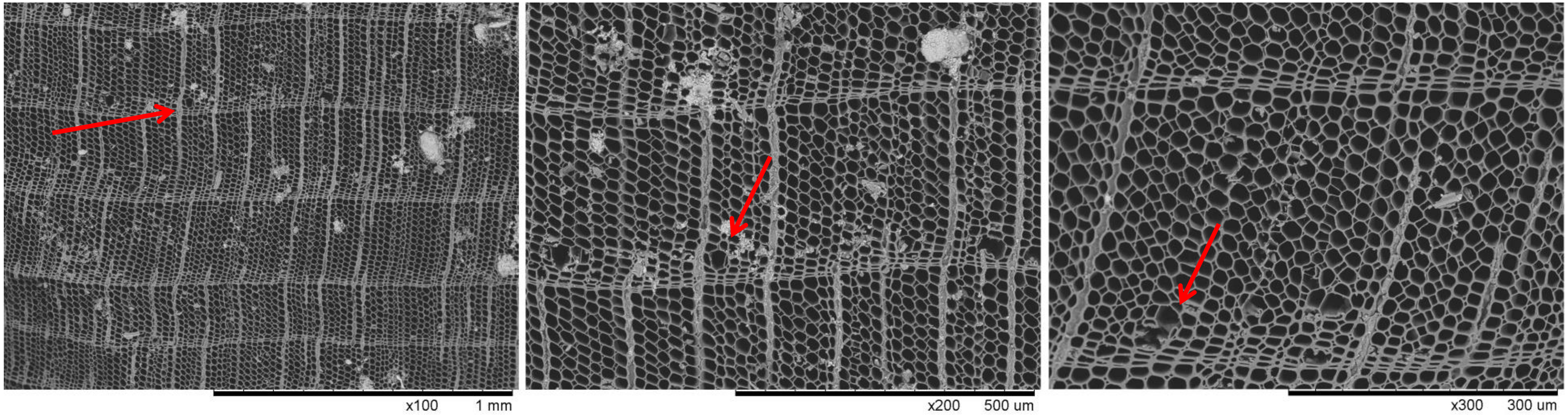


Figure 5.4: *Juniperus* (Çatalhöyük), traumatic canals and deformed tracheids.

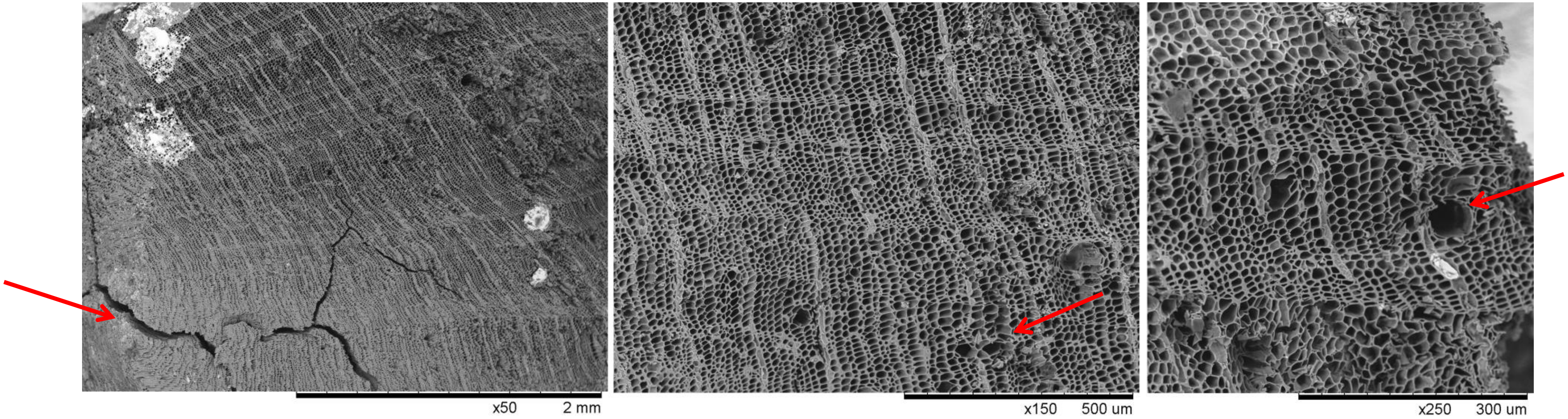


Figure 5.5: *Juniperus* (Çatalhöyük), scar/callus tissue (left), deformed tracheids, narrow and discontinuous rings (middle, right), trauma canal (right).

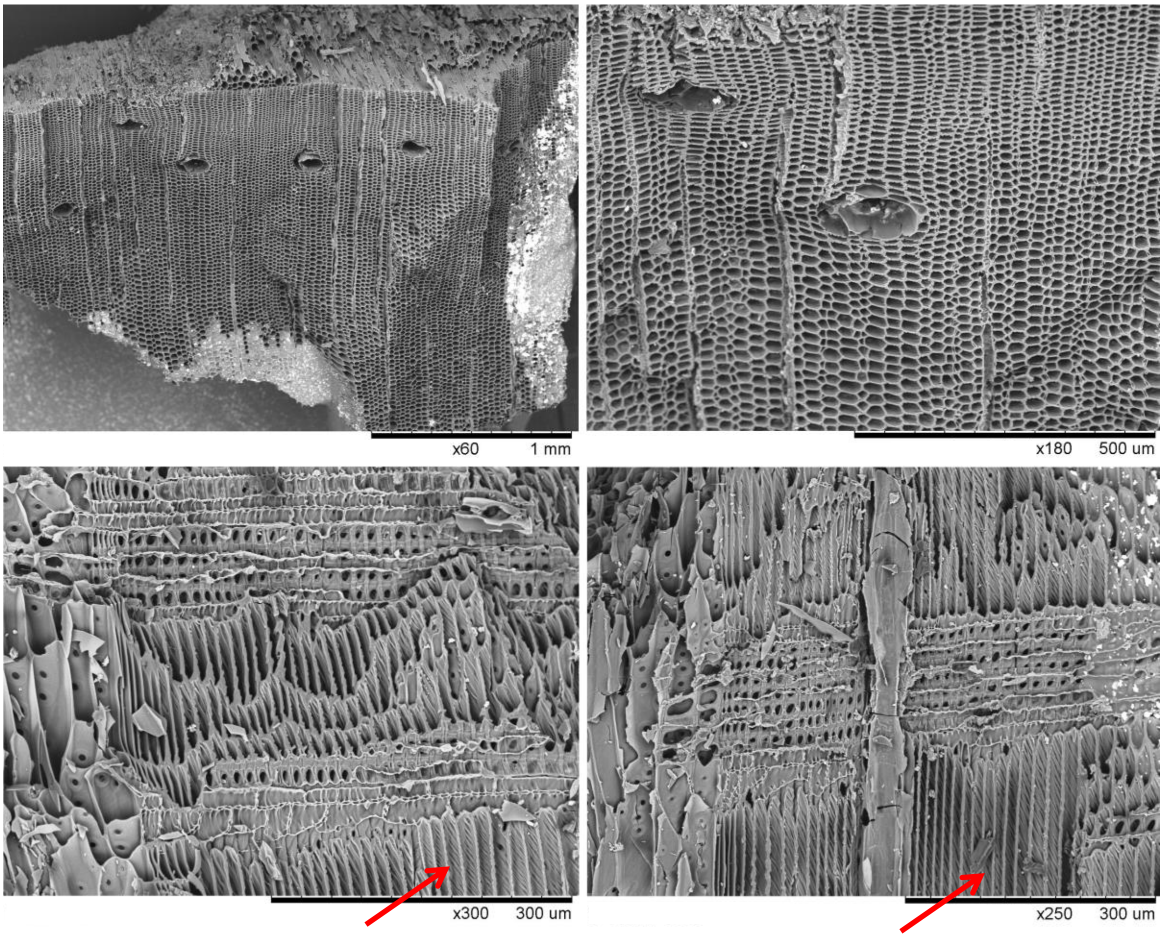


Figure 5.6: *Pinus* cf. *nigra* (Boncuklu), tension wood visible on the RLS (bottom)

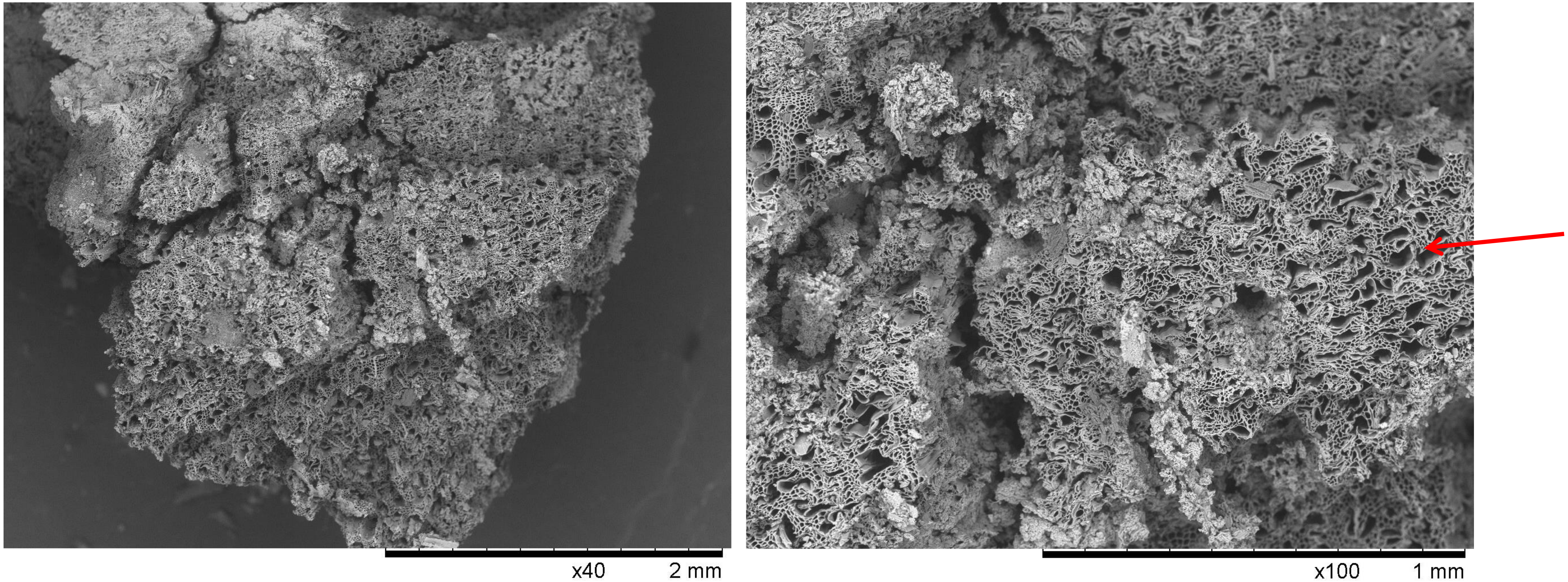


Figure 5.7: Salicaceae (Boncuklu), collapsed vessels, fibres and parenchyma tissue, most likely as a result of severe fungal degradation

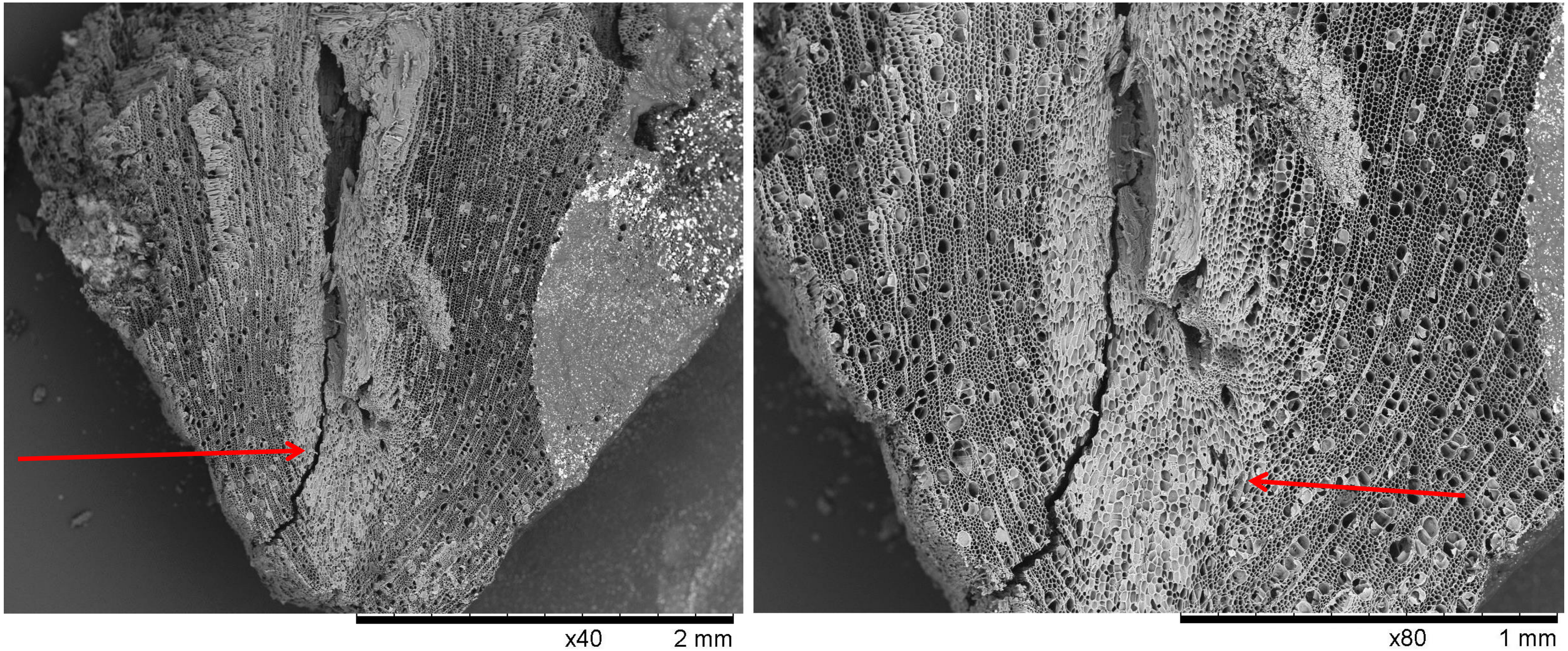


Figure 5.8: Salicaceae (Boncuklu), scar/callus tissue, possibly radial growth over shed twig.

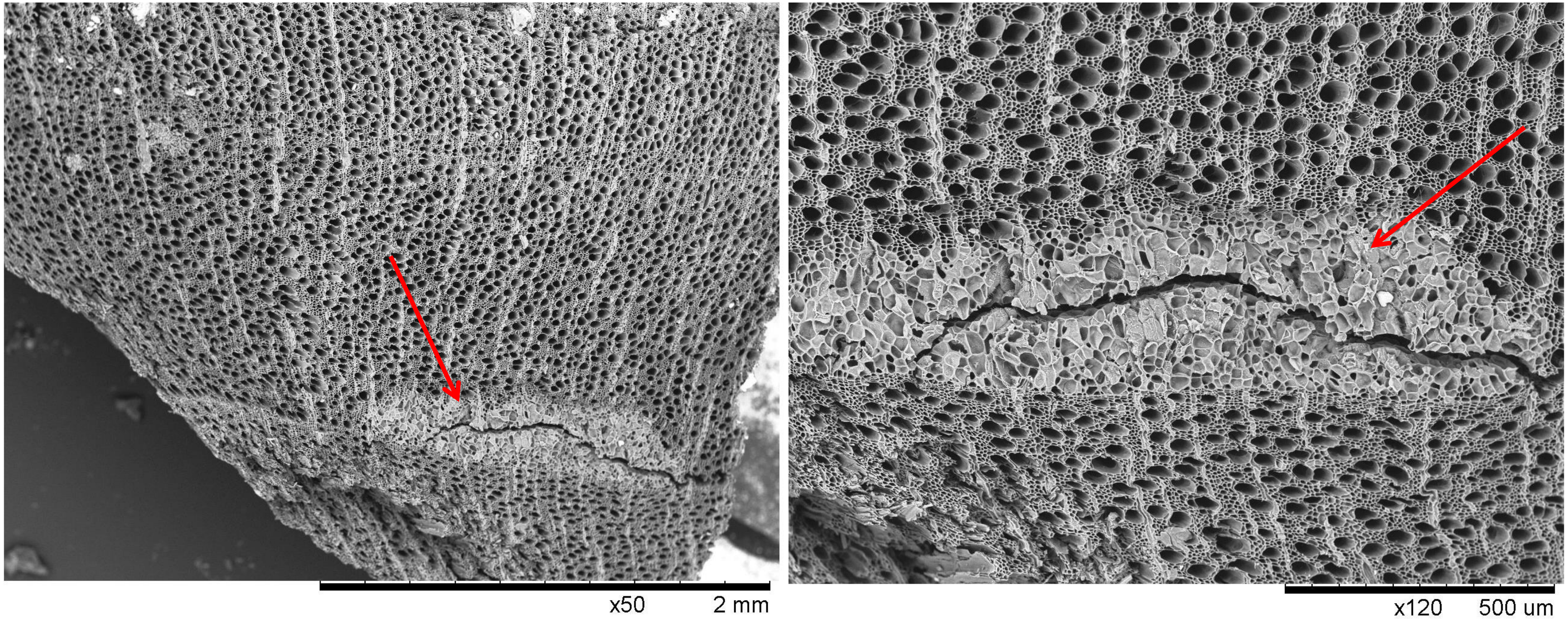


Figure 5.9: Maloideae (Çatalhöyük), scar/callus tissue

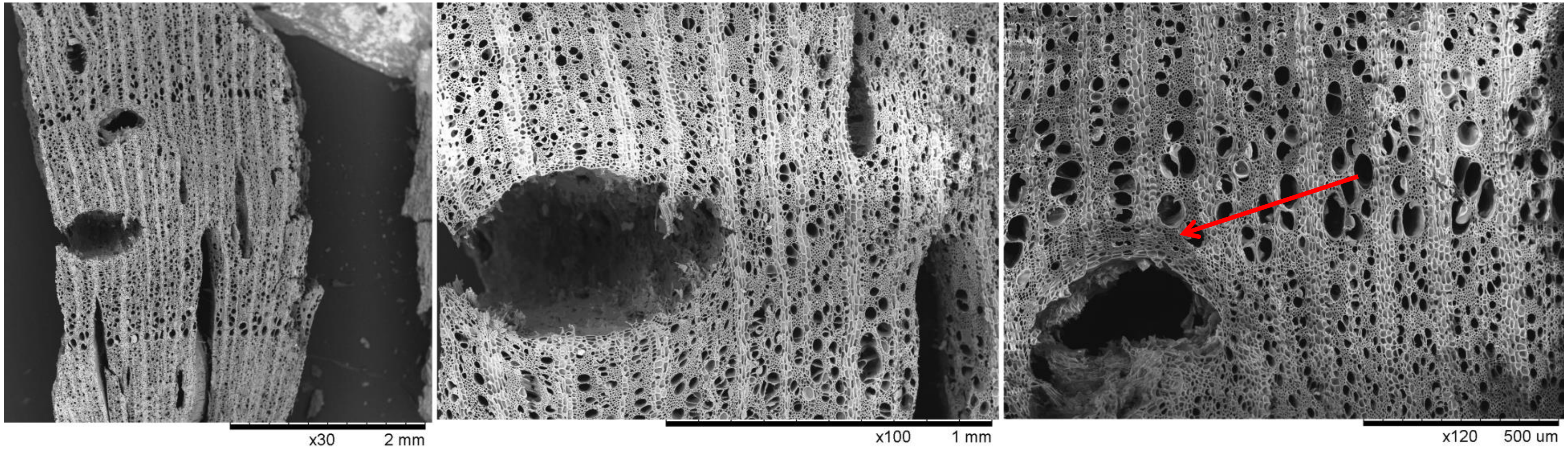


Figure 5.10: *Amygdalus* (Çatalhöyük), scar/callus over wound, possible insect damage, tissue re-orientation and radial overgrowth can be seen on closer image on the right.

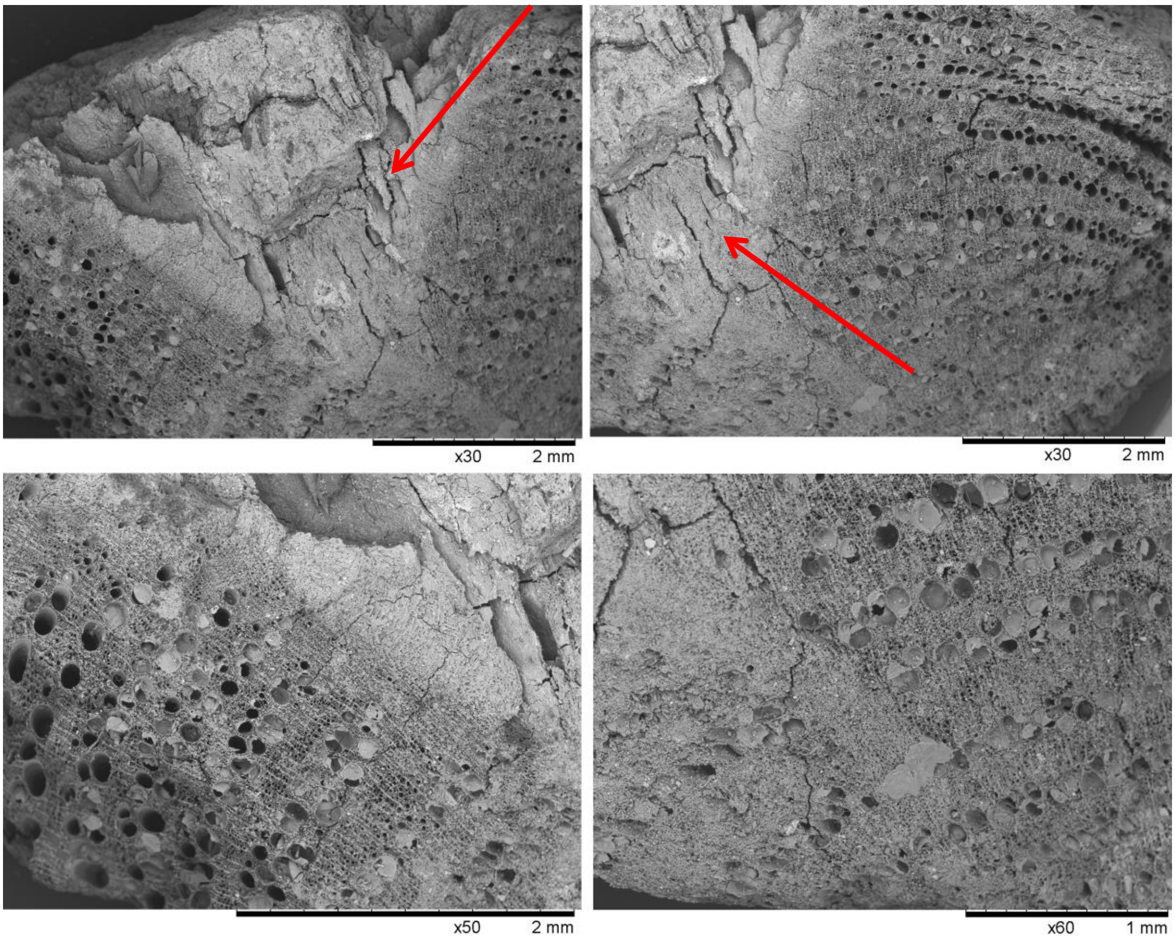


Figure 5.11: *Quercus* (Çatalhöyük), scar/callus tissue, radial overgrowth.

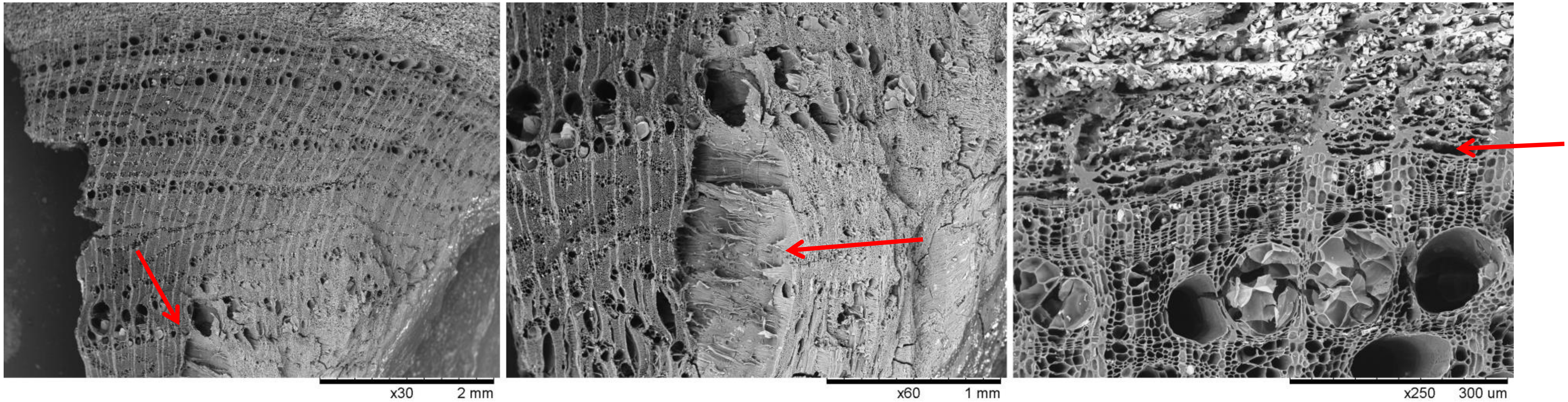


Figure 5.12: *Celtis* (Çatalhöyük), scar/callus tissue (left, middle), bark present: possibly autumn/winter cut (right).

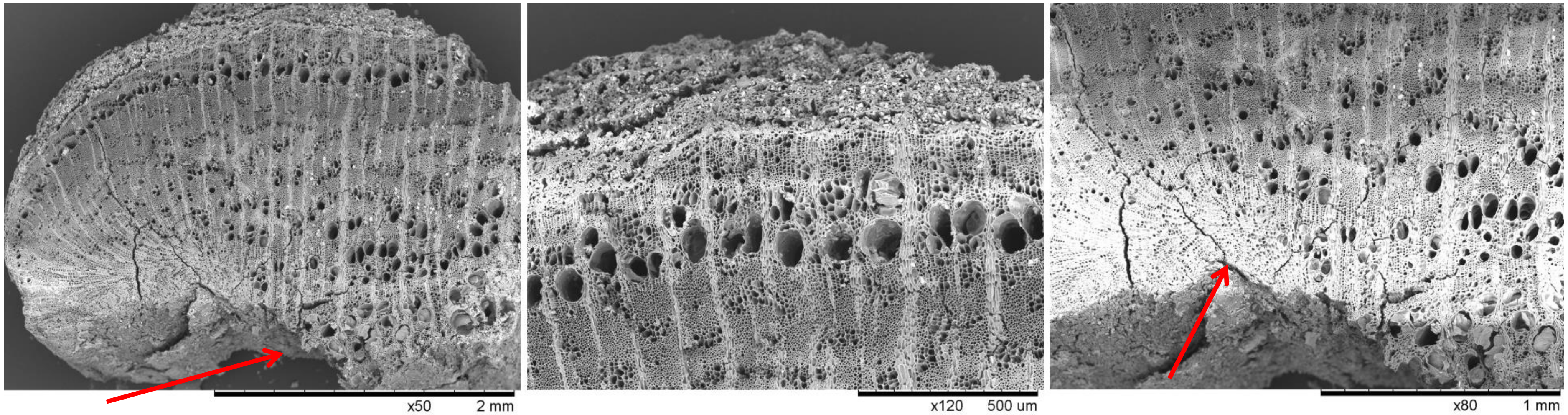


Figure 5.13: Ulmaceae (Çatalhöyük), scar/callus tissue (left and far right). Wound or damage occurred shortly after initial earlywood formation, radial overgrowth continued during the latewood and earlywood of the following year. Preserved bark (middle) indicates cutting ensued in autumn/winter.

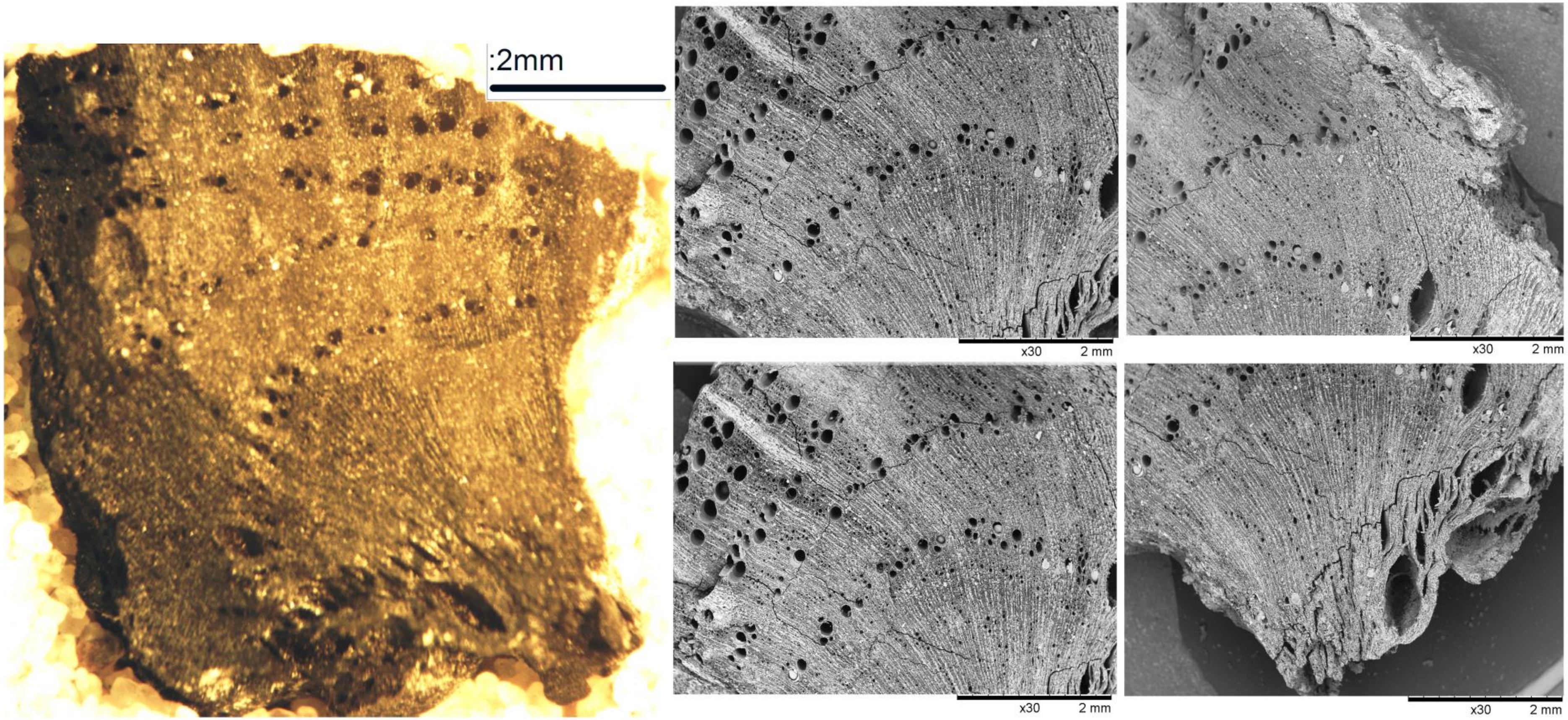


Figure 5.14: *Quercus* (Çatalhöyük), radial overgrowth, possibly covering scar or other growth anomaly, left specimen imaged with Stereozoom microscope camera, right with SEM.

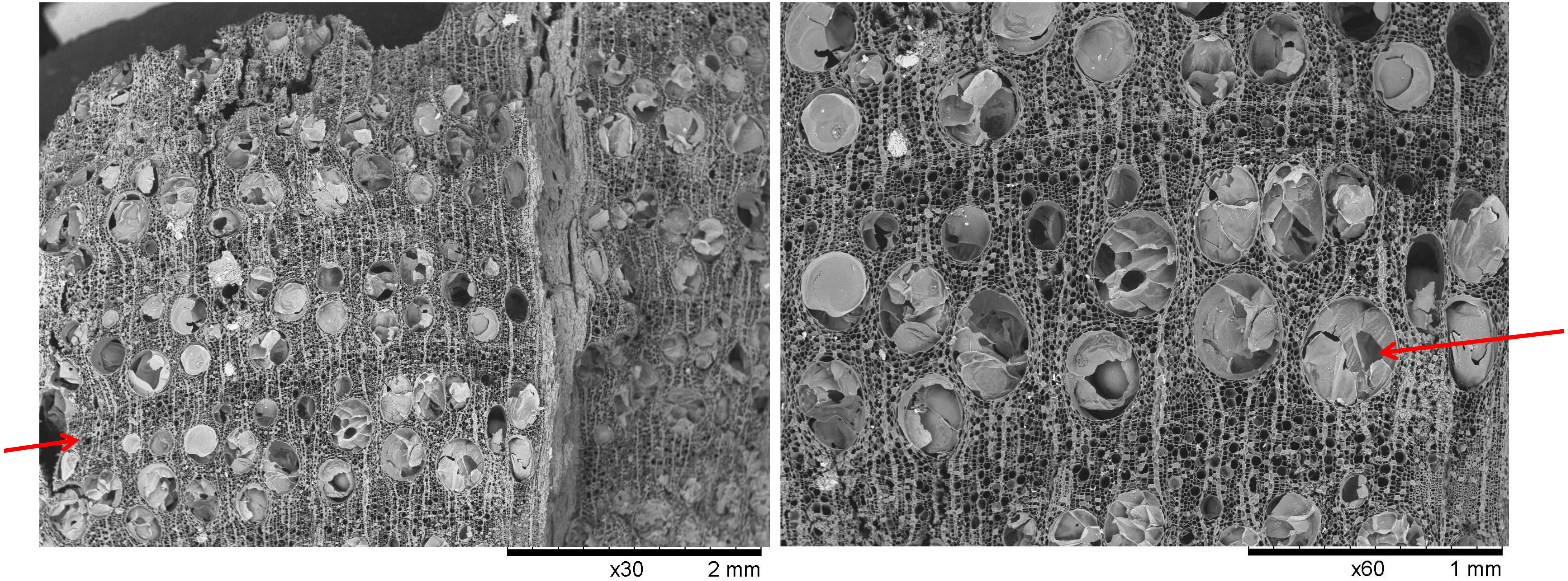


Figure 5.15: *Quercus* (Çatalhöyük), narrow growth rings with limited latewood formation. see also tyloses in earlywood vessels (right).

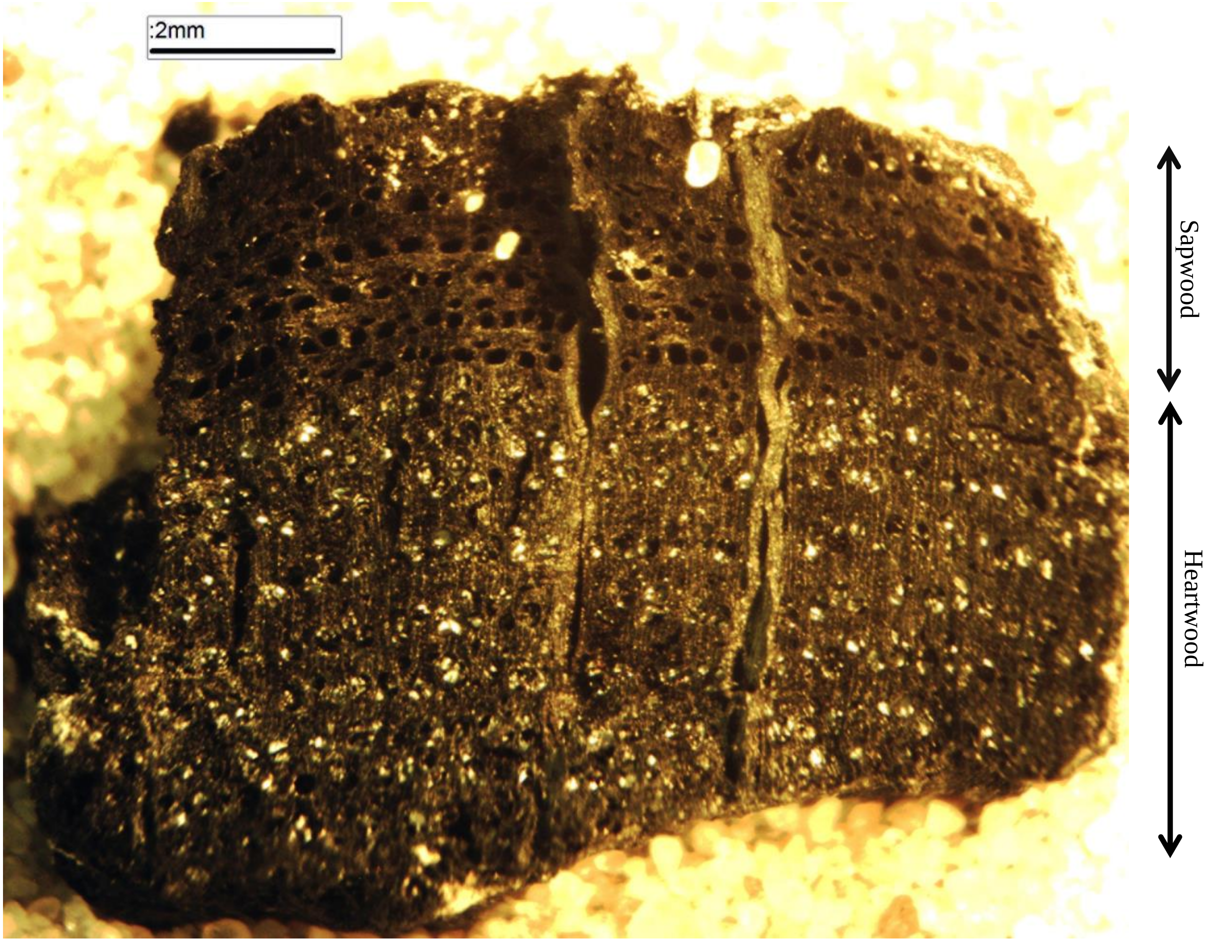


Figure 5.16: *Quercus* (Çatalhöyük), transition zone from heartwood (with tyloses) to sapwood (without tyloses) (Stereo-zoom microscope digital image).

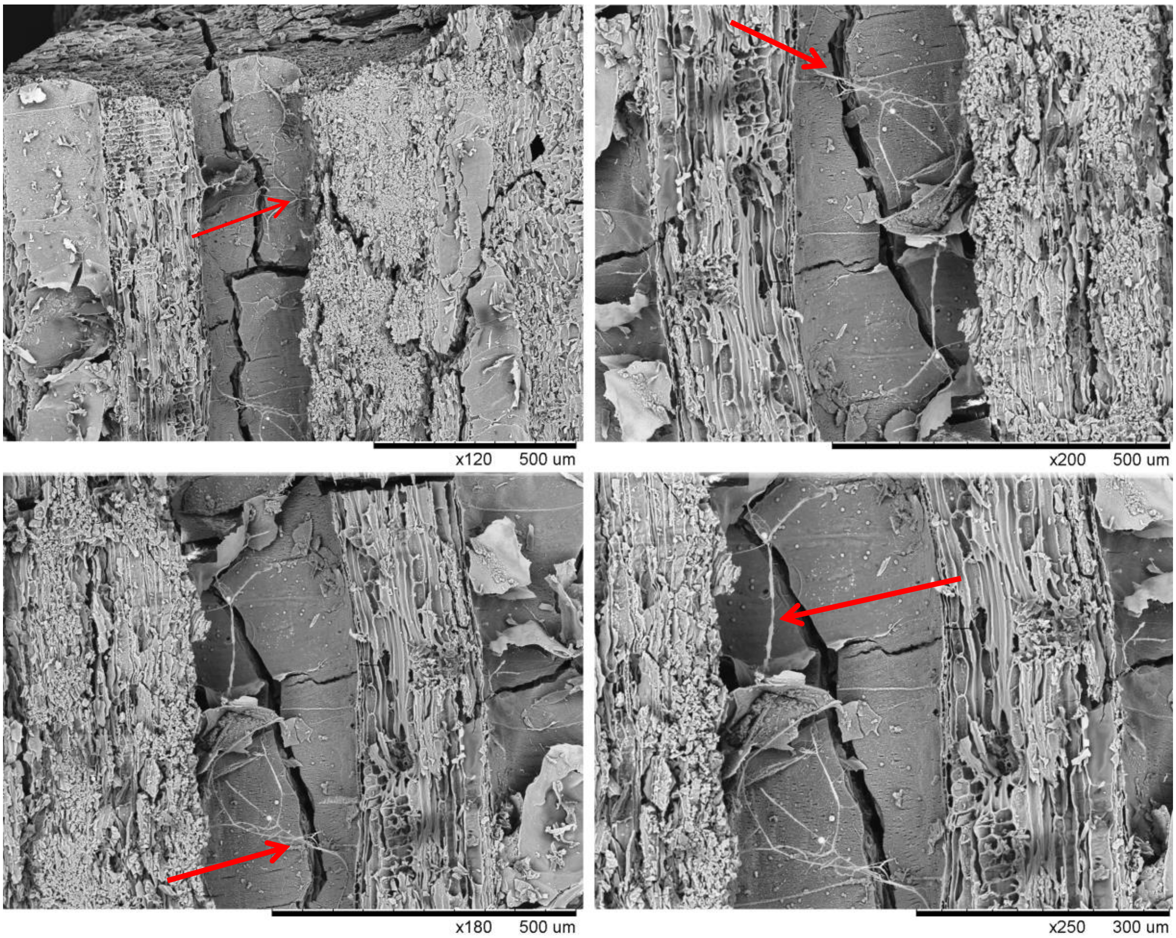


Figure 5.17: Quercus (Çatalhöyük), fungal mycelia attached to vessel walls.

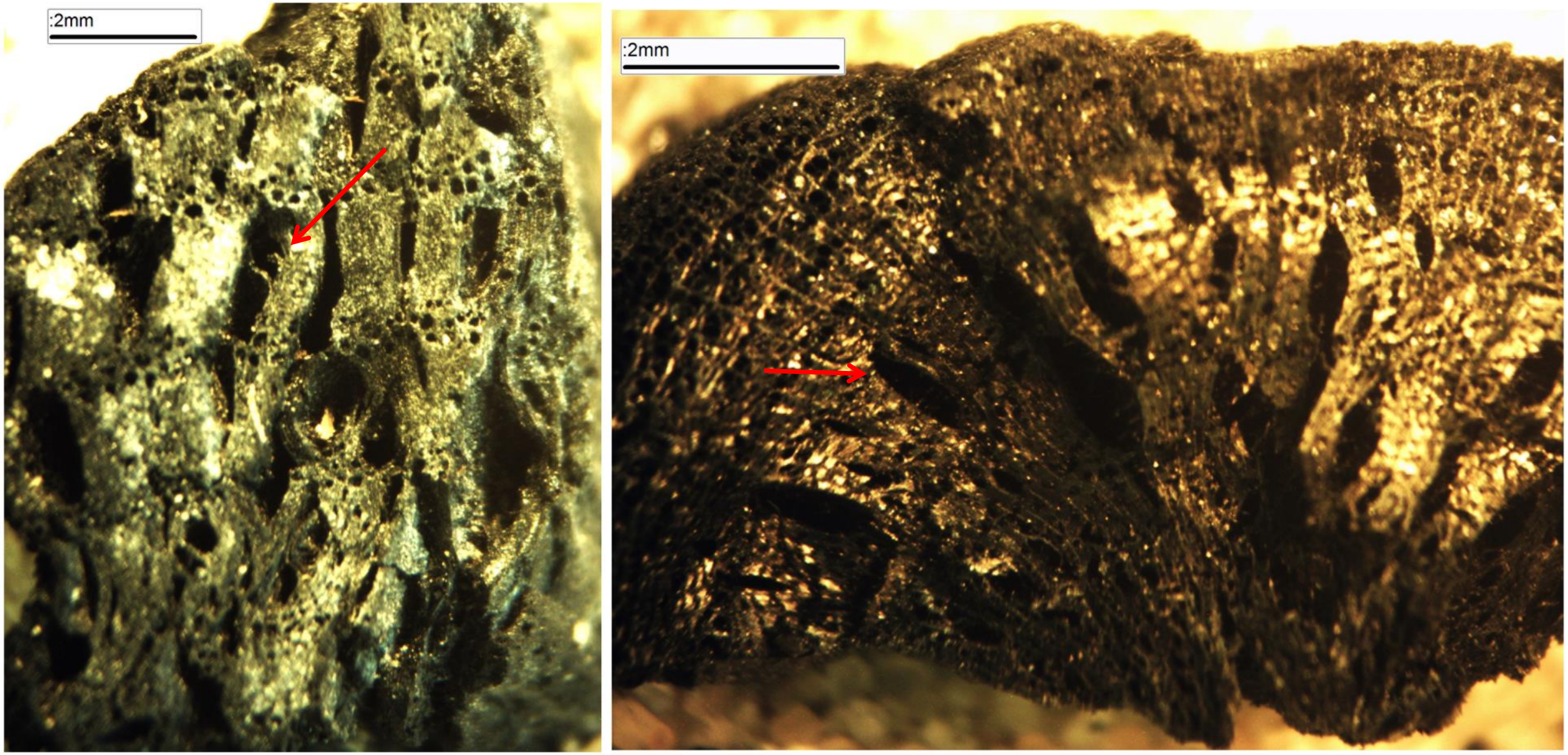


Figure 5.18: Quercus (left), Ulmaceae (right), (Çatalhöyük), radial cracks (Stereo- zoom microscope digital images).

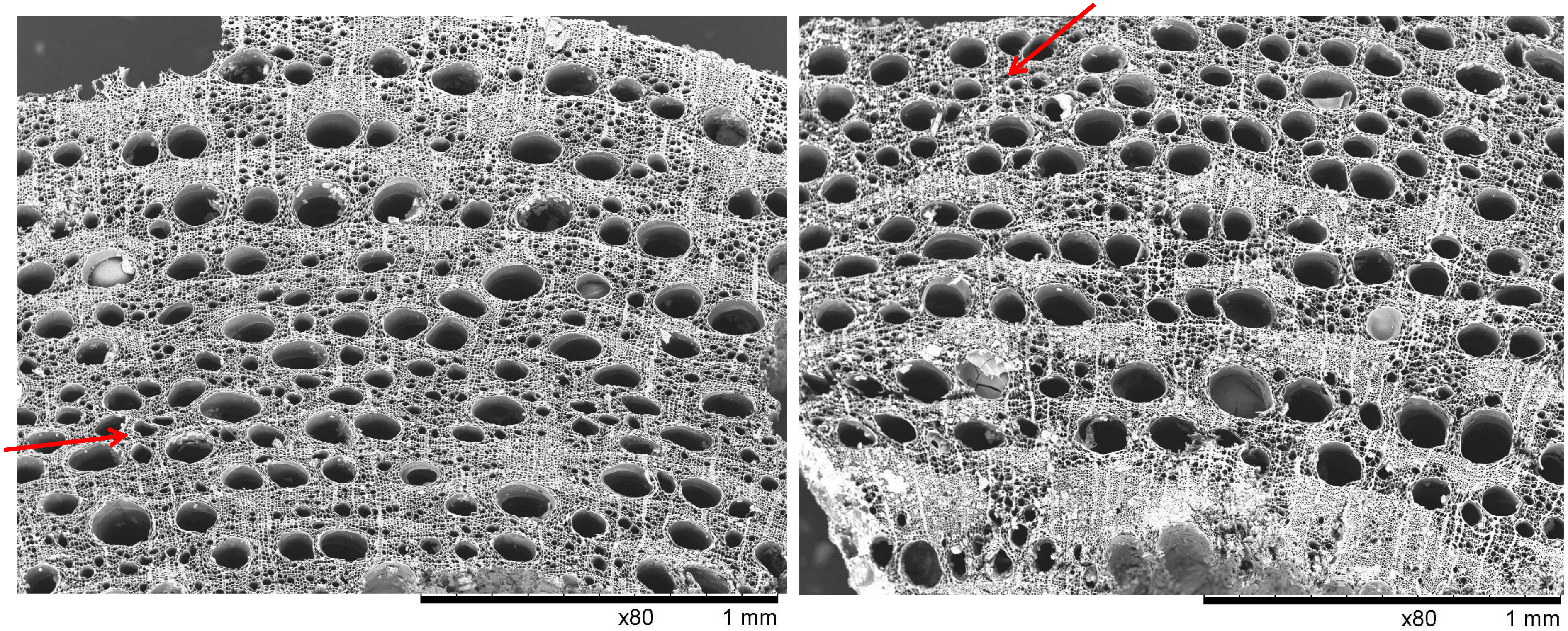


Figure 5.19: *Quercus* (Çatalhöyük), round wood fragment with narrow and discontinuous rings, possibly formed as a result of browsing pressure.

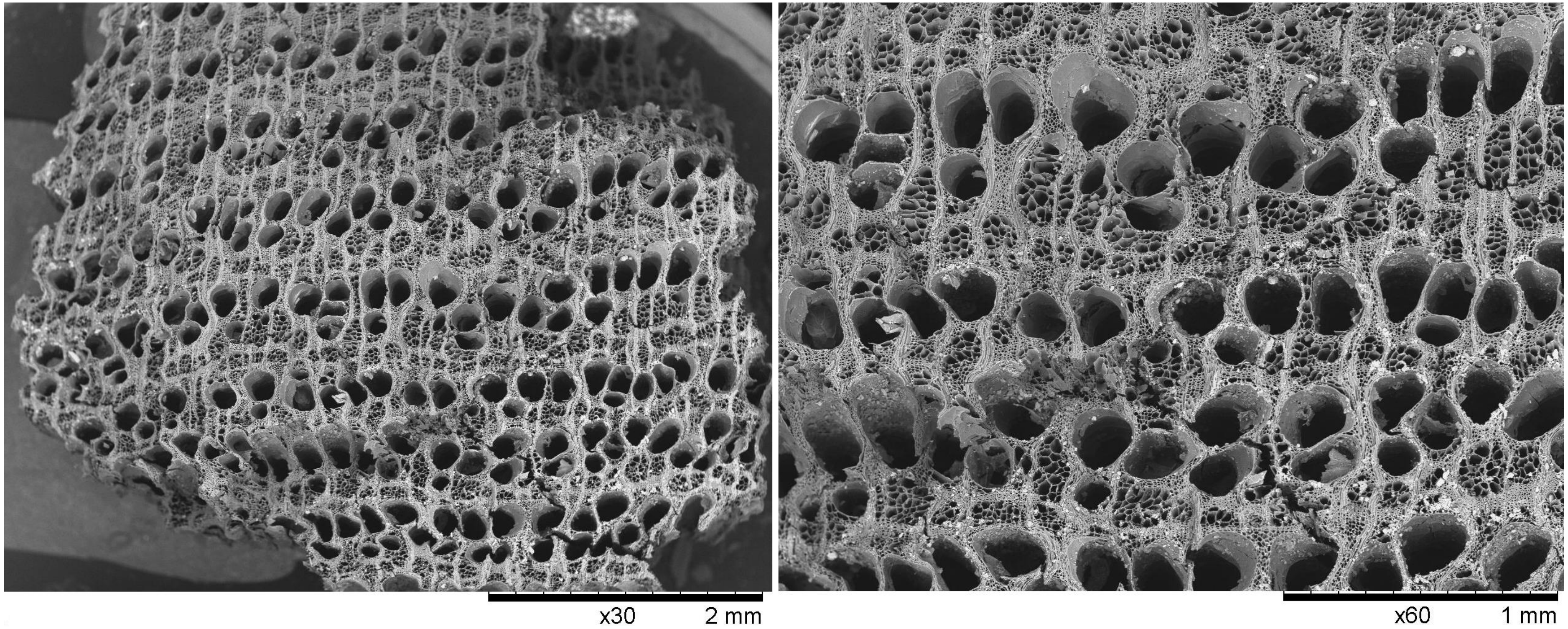


Figure 5.20: *Ulmus* (Çatalhöyük), narrow growth rings.

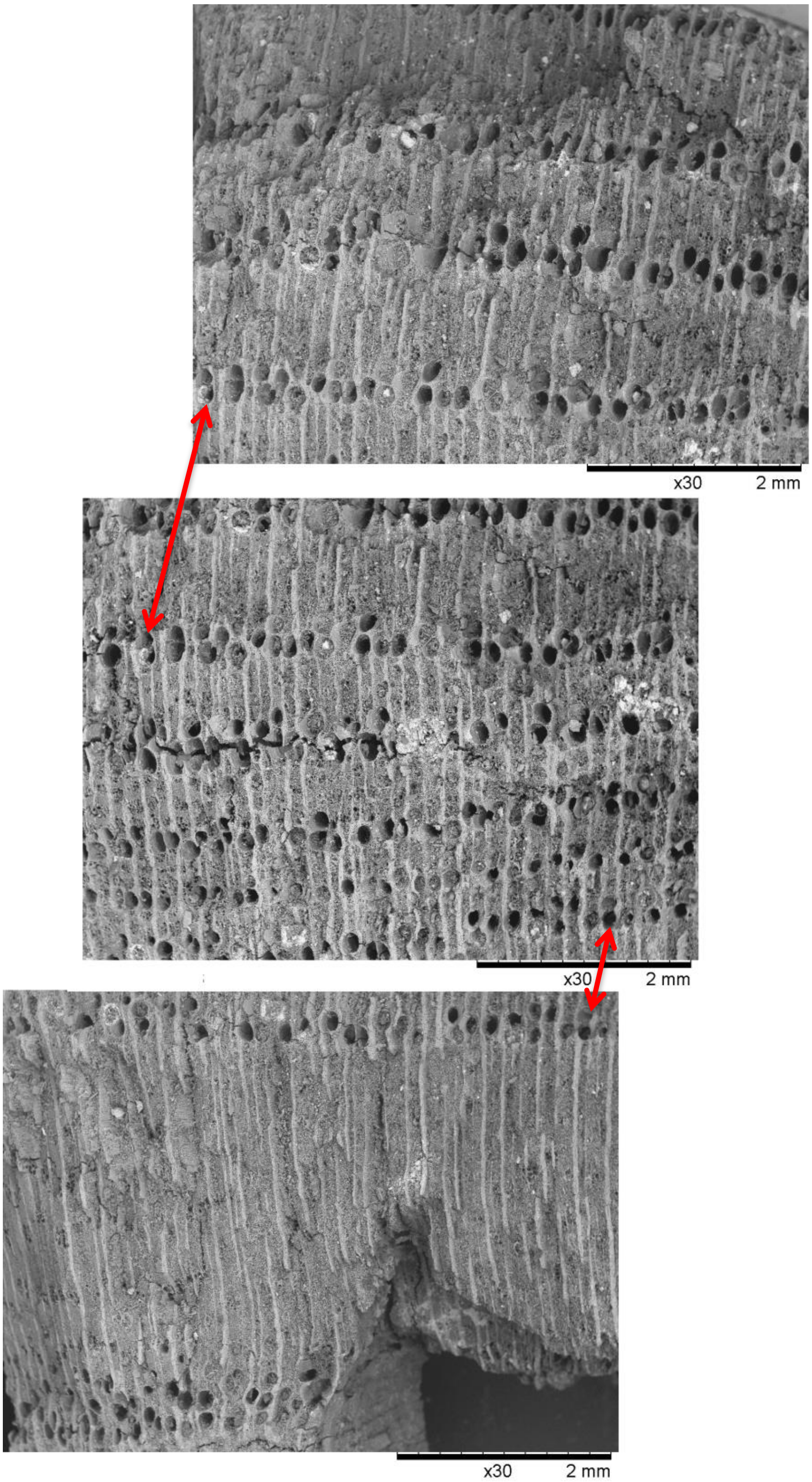


Figure 5.21: *Ulmus* (Çatalhöyük), adult stem wood, fluctuating ring width pattern possibly as a reaction to growth improvement following thinning (red arrows indicate points of overlap, all three images belong to the same specimen)

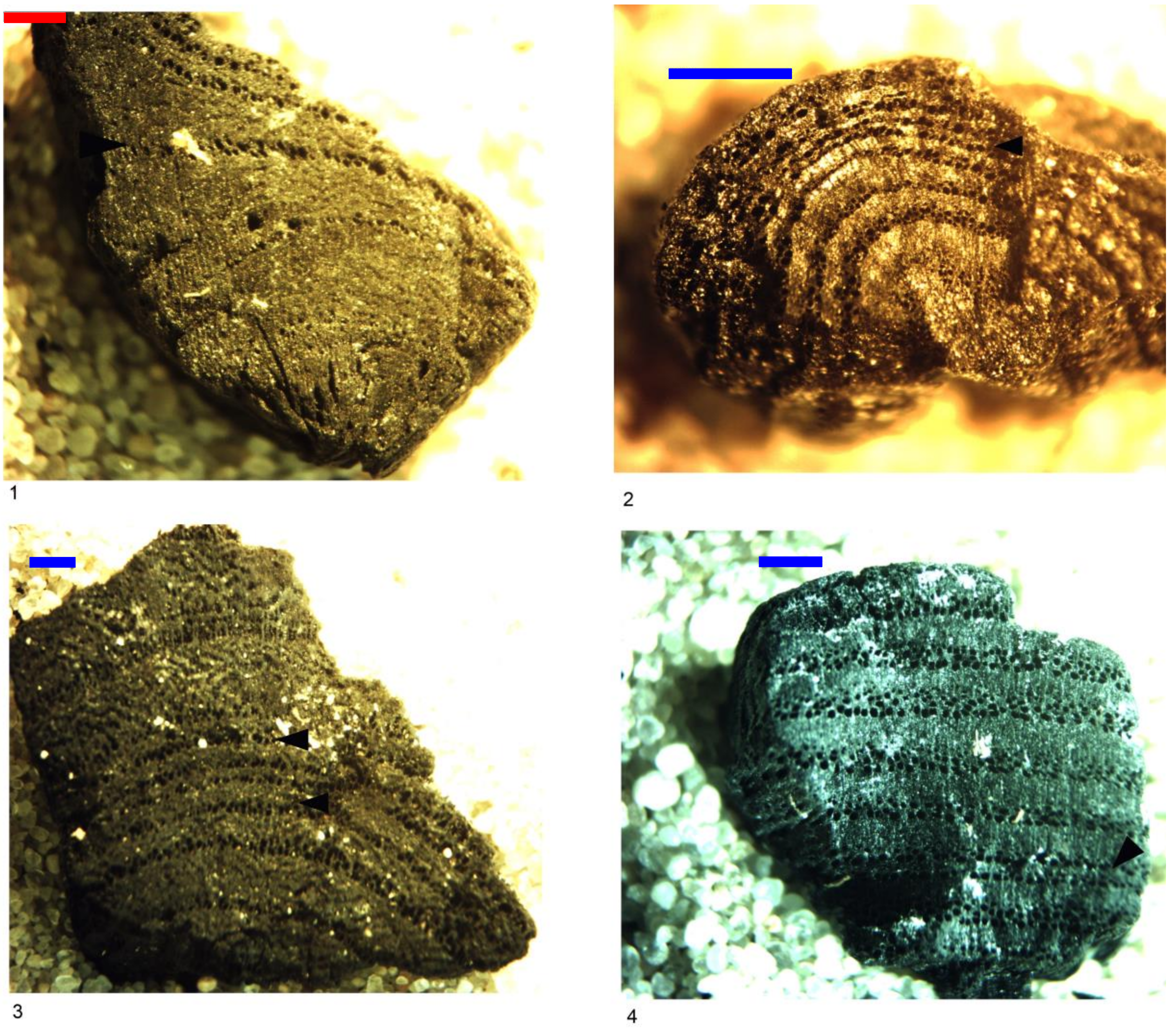


Figure 5.22: Growth ring width variability observed in specimens from Çatalhöyük (zoom stereomicroscope digital images; scale 1mm).

1. *Quercus*, wedging ring, radial overgrowth.

2. *Quercus*, short shoot, growth reduction indicated by arrow, possibly in response to increasing competition for light.

3. *Celtis*, growth reduction (indicated by lower arrow) lasting 4 years, followed by abrupt improvement in radial growth, possibly in response to thinning.

4. *Fraxinus*, short period of growth reduction, possibly in response to extreme weather (e.g., aridity).

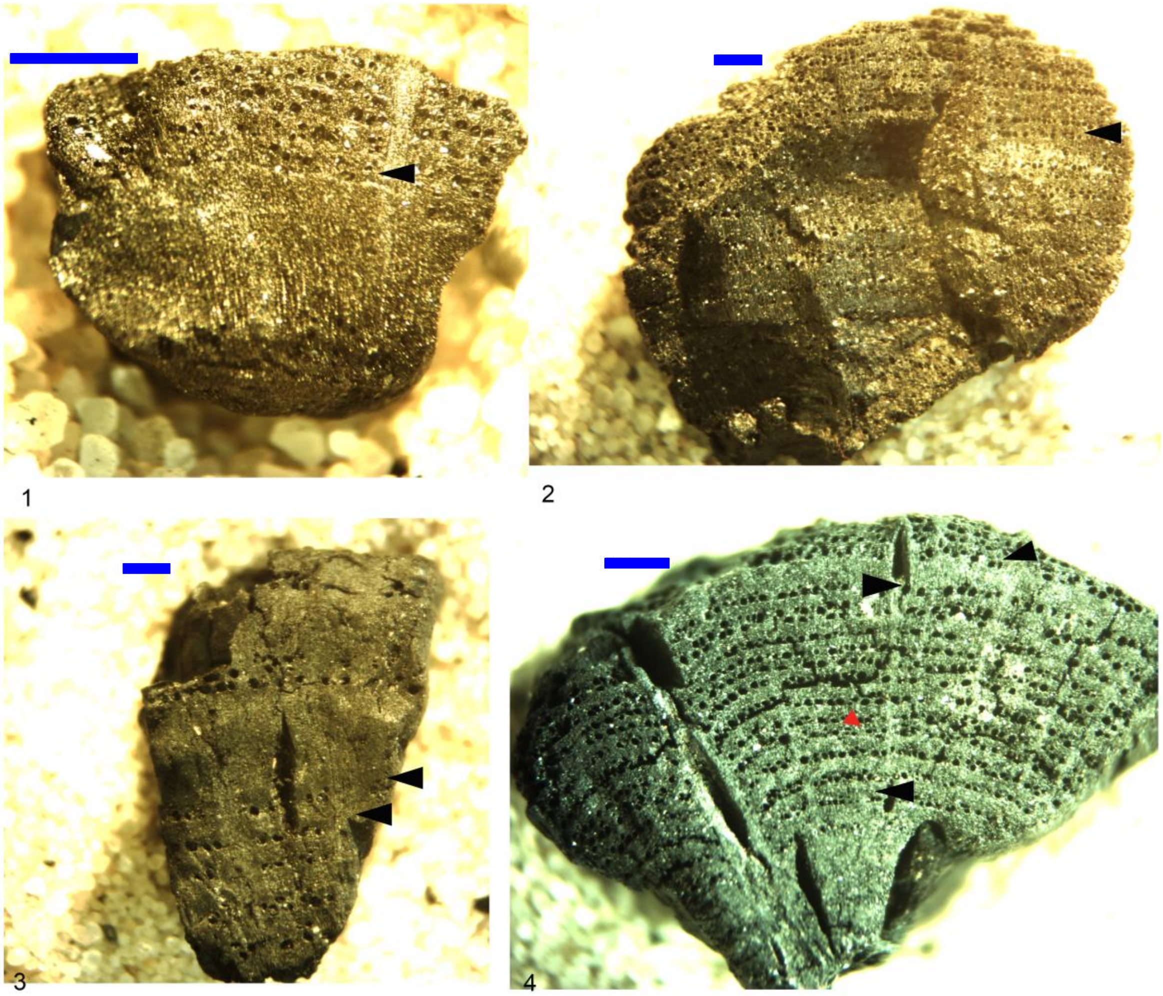


Figure 5.23: Growth ring width variability observed in specimens from Çatalhöyük (zoom stereomicroscope digital images; scale 1mm).
1. *Quercus*, fragment of heartwood, arrow indicates sudden growth reduction, possibly as a response to browsing and closed canopy.
2. *Fraxinus*, adult stem wood, arrow indicates beginning of reduced growth, possibly in response to increasing competition.
3. *Quercus*, adult stem wood, lower arrow denotes the beginning of early wood in year with limited radial growth; upper arrow denotes the beginning of abrupt growth improvement, possibly in response to thinning of the canopy.
4. *Quercus*, sapling/short shoot or dwarfed stem wood; lower black arrow indicates beginning of growth reduction. Red arrow indicates discontinuous ring, upper arrow marks one year of improved growth. Pattern likely reflects browsing impacts and competition for light.

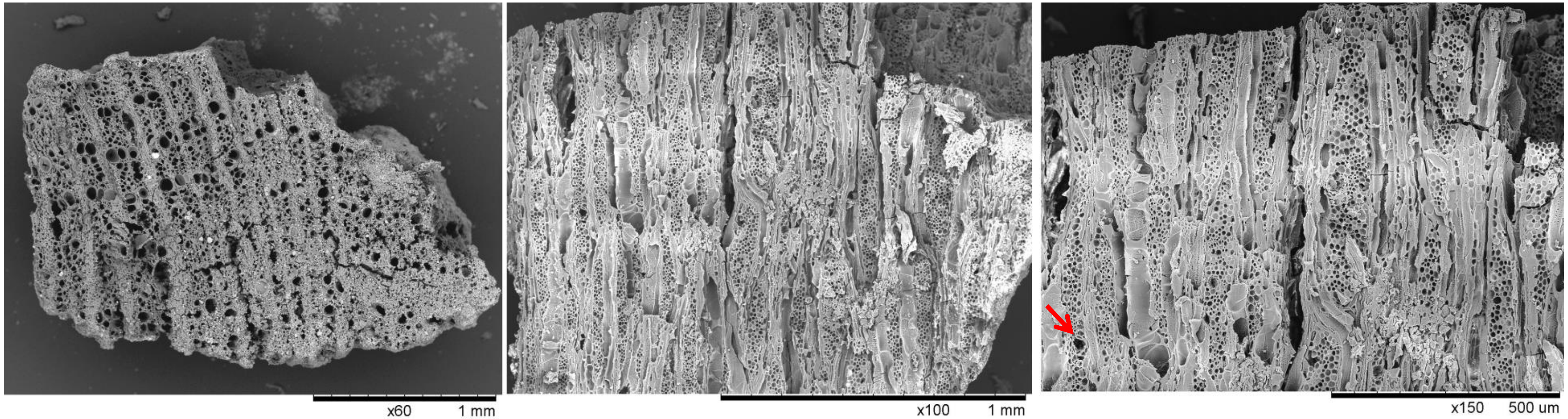


Figure 5.24: *Amygdalus* (Pınarbaşı, 9th millennia).
Left: transverse section, note narrow growth rings, dense vessels and one row of earlywood vessels.
Middle and right: Tangential longitudinal section, note rays generally (3)5-8 cells wide, some gum ducts are also visible (arrow).

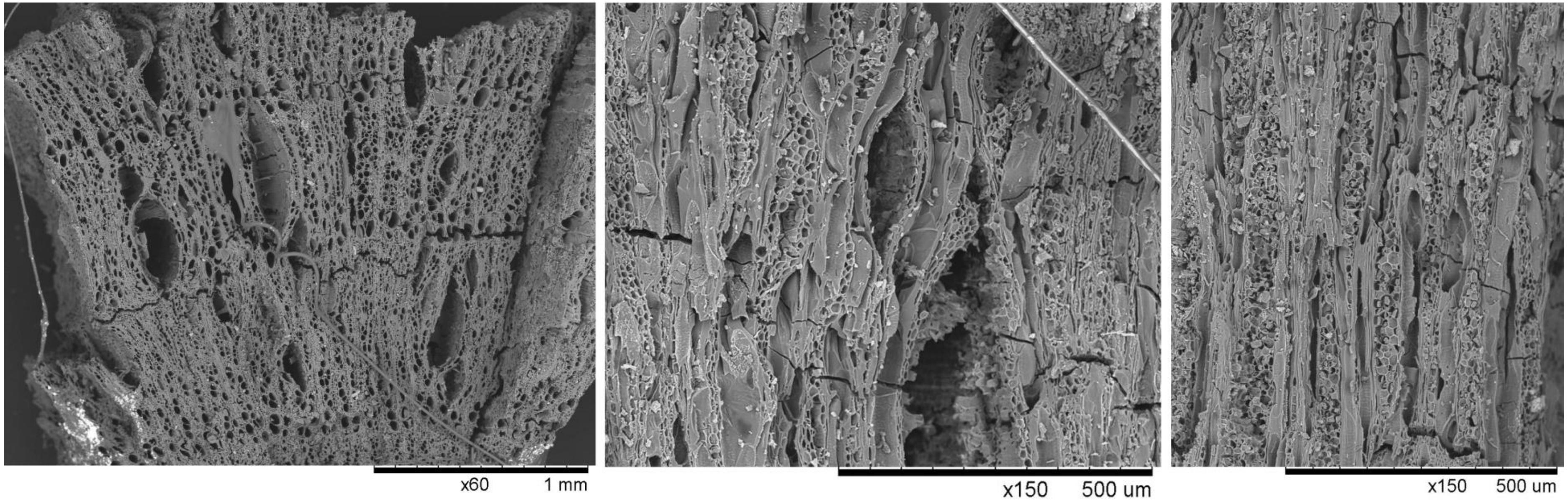


Figure 5.25: *Amygdalus* (Boncuklu).
Left: transverse section, note relatively wide growth rings, dense vessels and 2-3 rows of earlywood vessels.
Middle and right: Tangential longitudinal section, note rays generally (1)3-5 cells wide.

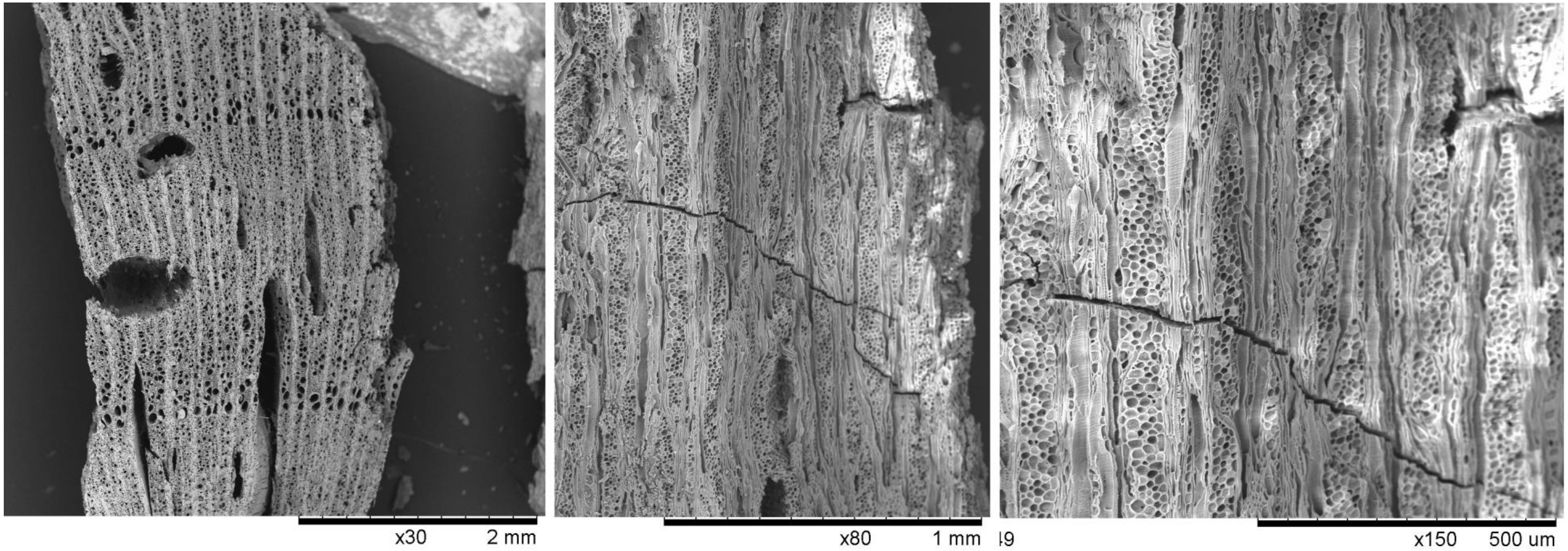


Figure 5.26: Amygdalus (Çatalhöyük).
Left: transverse section, note wide growth rings and 2-4 rows of earlywood vessels.
Middle and right: Tangential longitudinal section, note rays generally (1)3-5 cells wide.

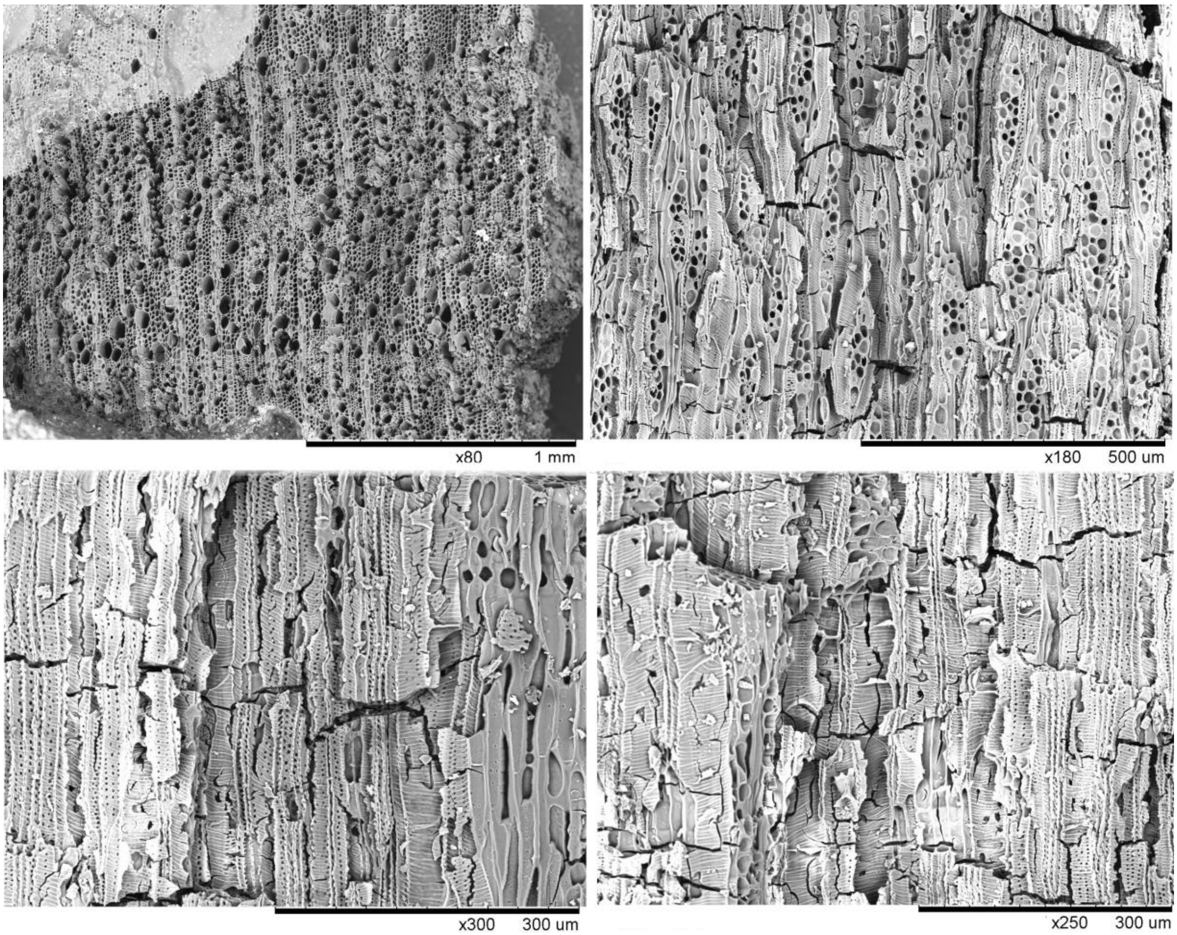


Figure 5.27: cf. *Arbutus* (Boncuklu), transverse (top left), tangential longitudinal (top right) and radial longitudinal (bottom) sections.

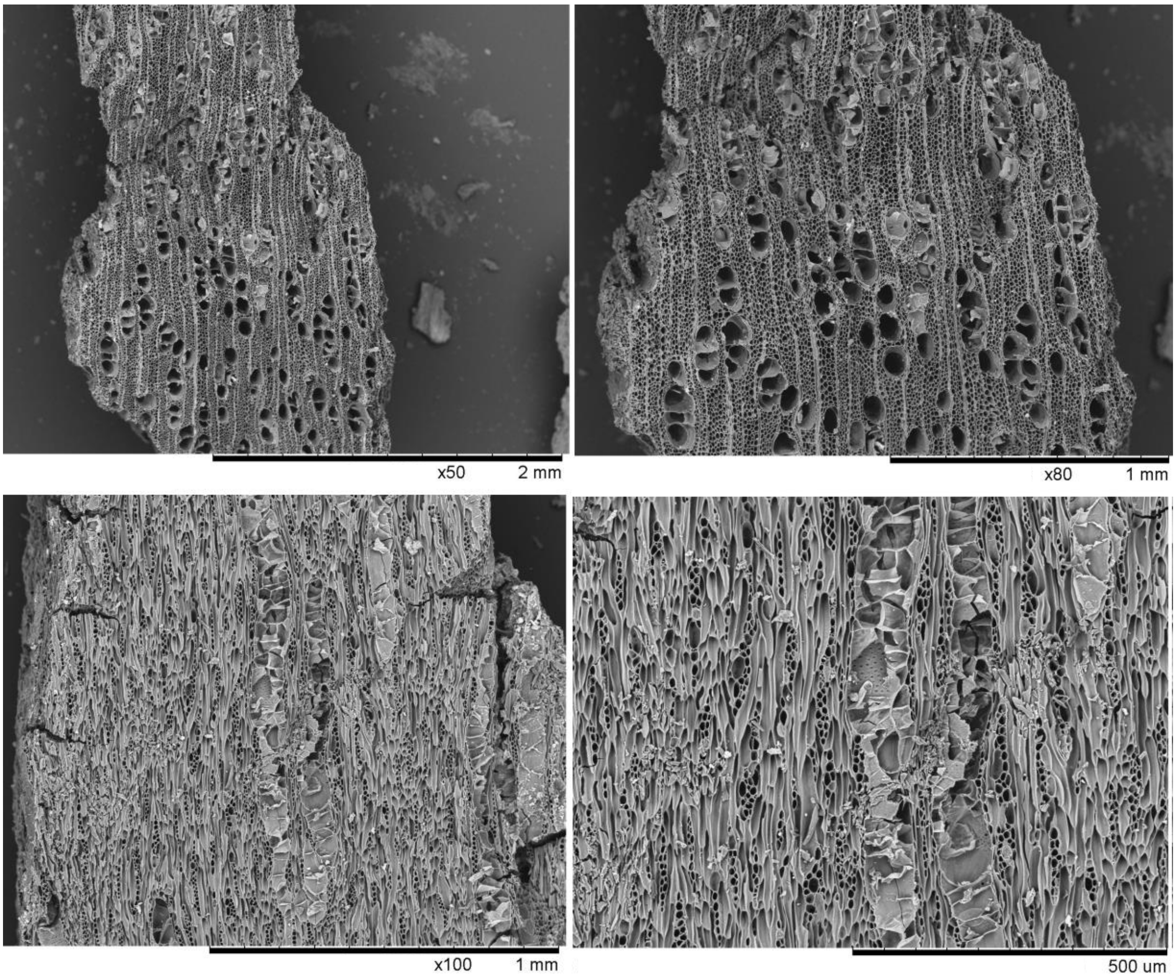


Figure 5.28: cf. *Ziziphus* (Boncuklu). Transverse (top) and tangential longitudinal (bottom) sections.

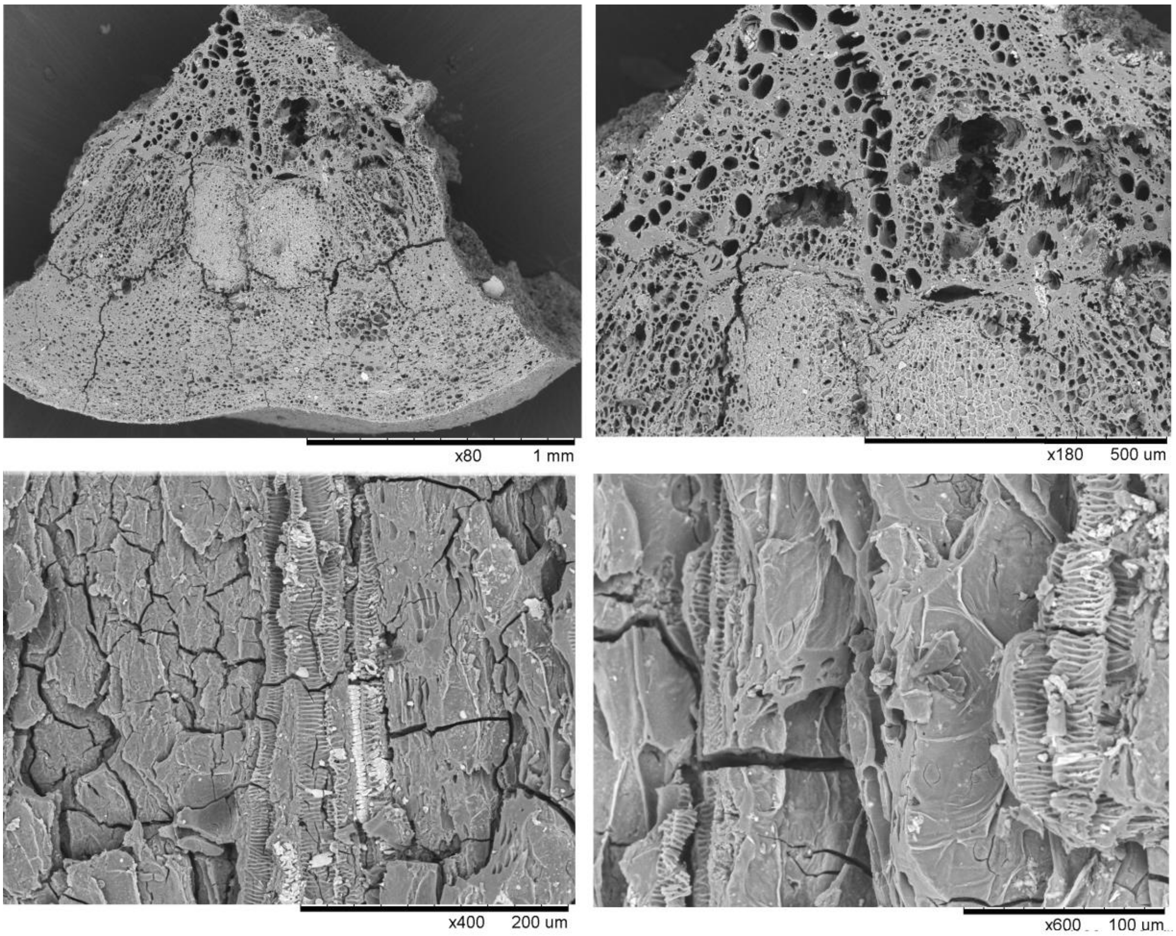


Figure 5.29: cf. Dicot stem (?) (Boncuklu). Transverse cross-section (top), note included phloem. Tracheary elements (bottom) with reticulate/net-like thickening.

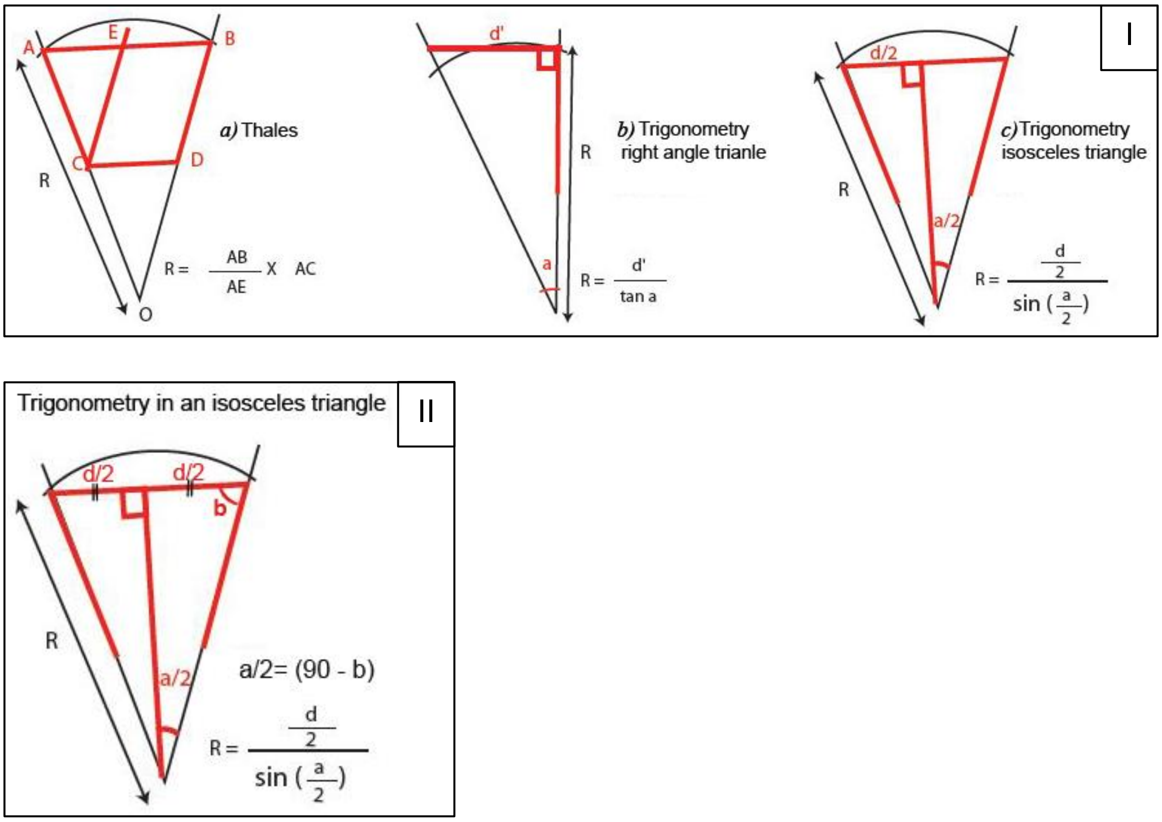


Figure 5.30: Method of calculation of estimated radius of curvature (R); minimum estimated diameter = 2xR.

(I) Methods tested by Paradis et al. 2013 (Ic is considered by Paradis et al. 2013 to produce the smallest margin of error).

(II) Method applied in the present study.

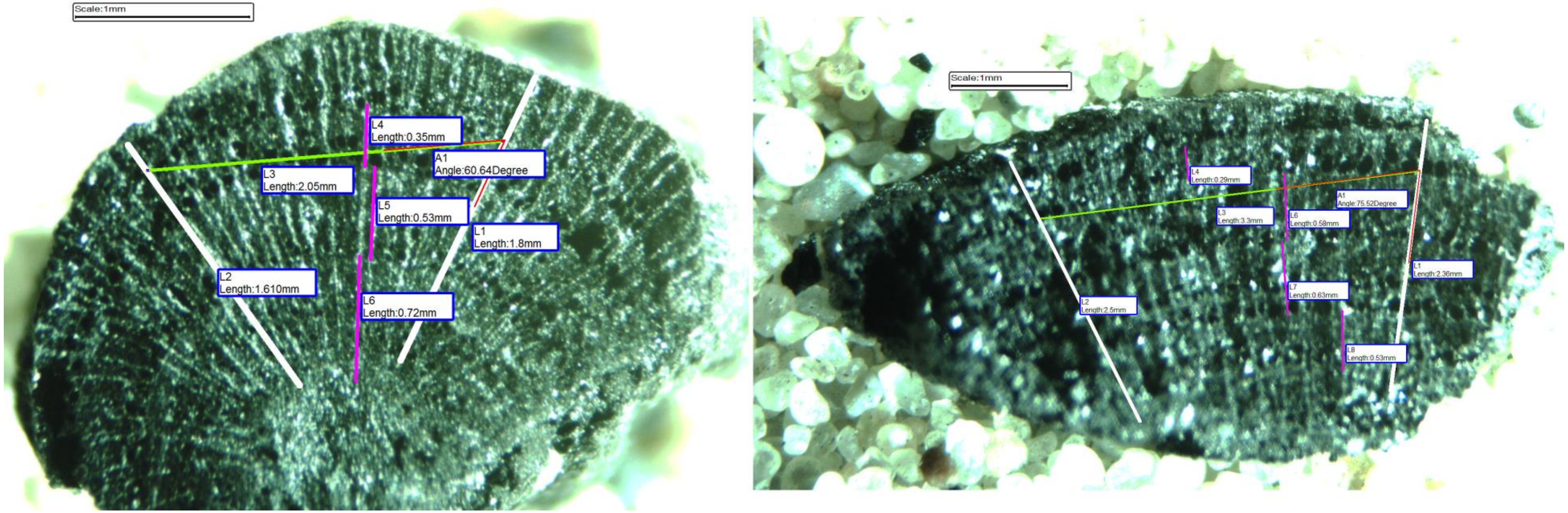


Figure 5.31: Examples of measurement protocol.

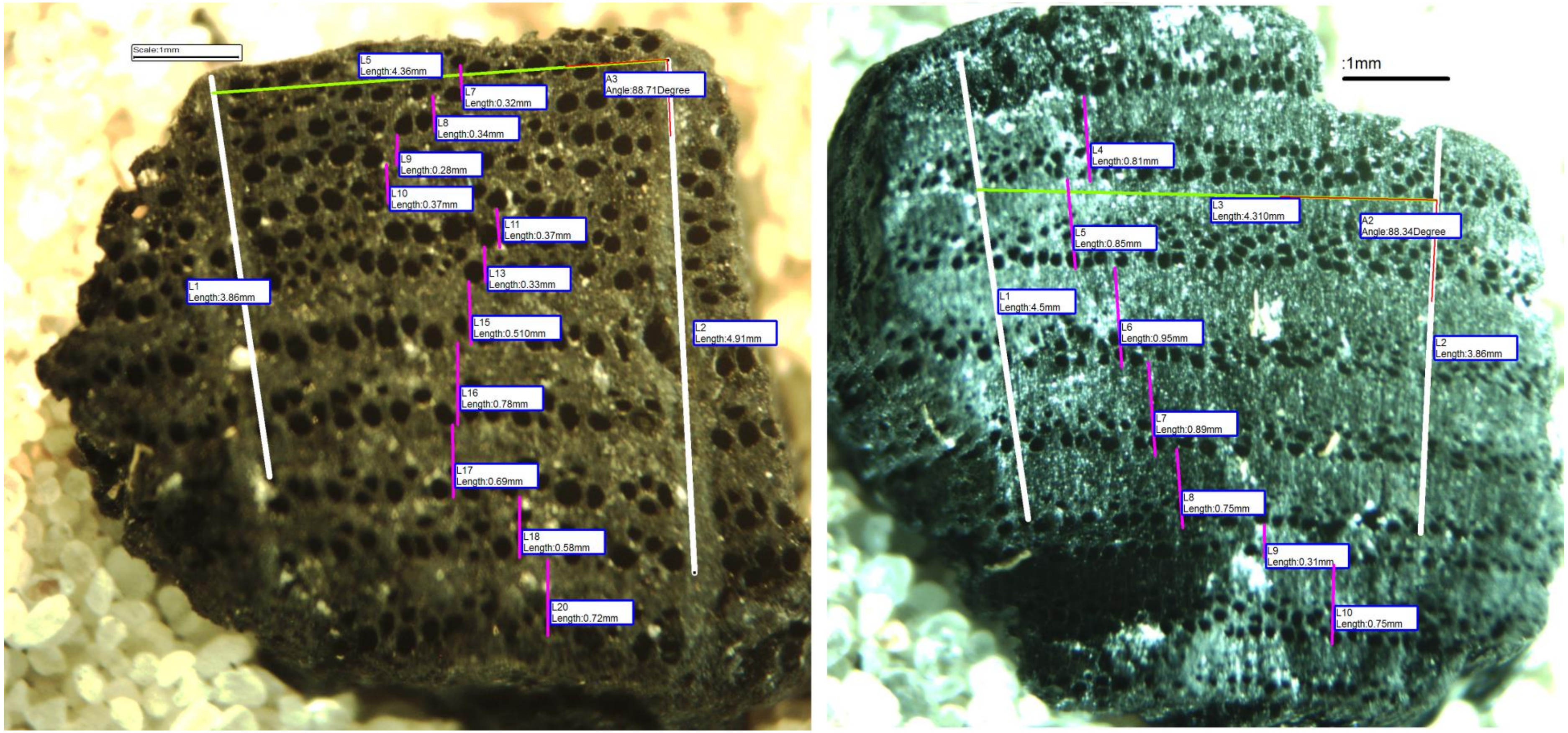


Figure 5.32: Examples of measurement protocol.

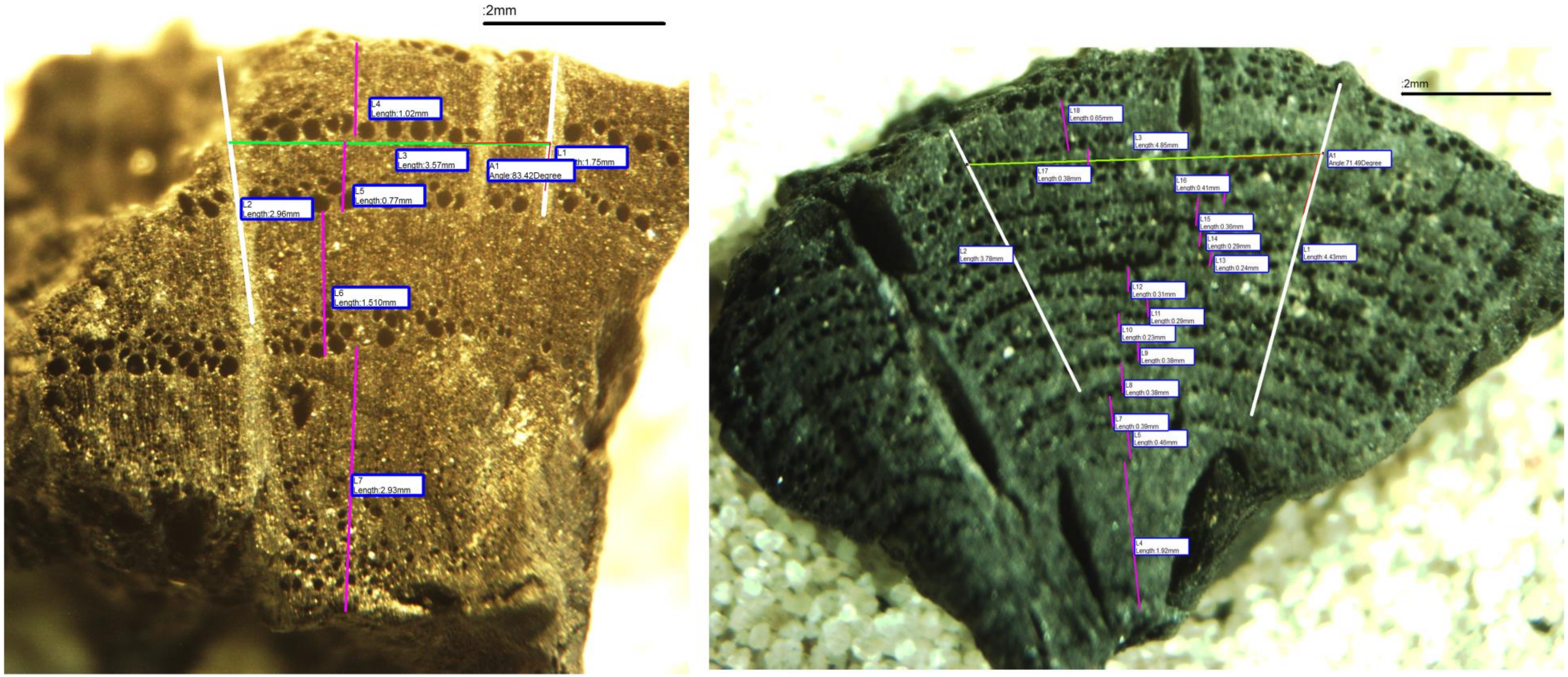


Figure 5.33: Examples of measurement protocol.

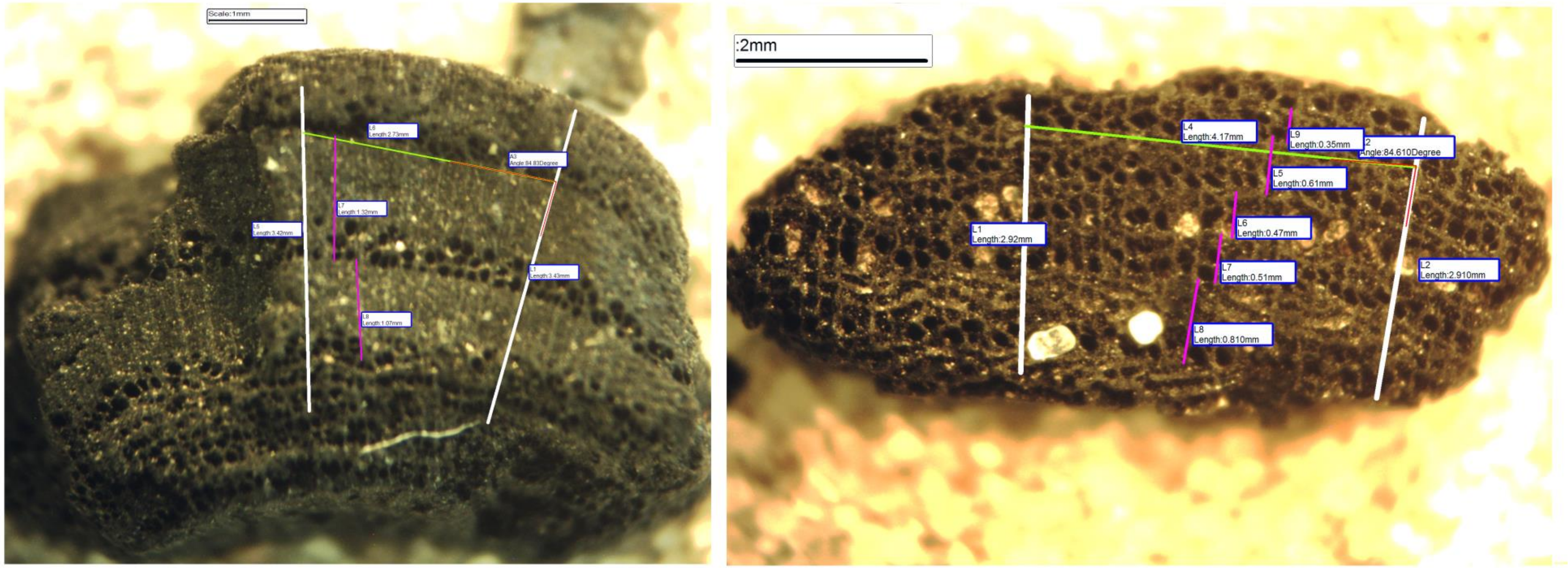


Figure 5.34: Examples of measurement protocol.

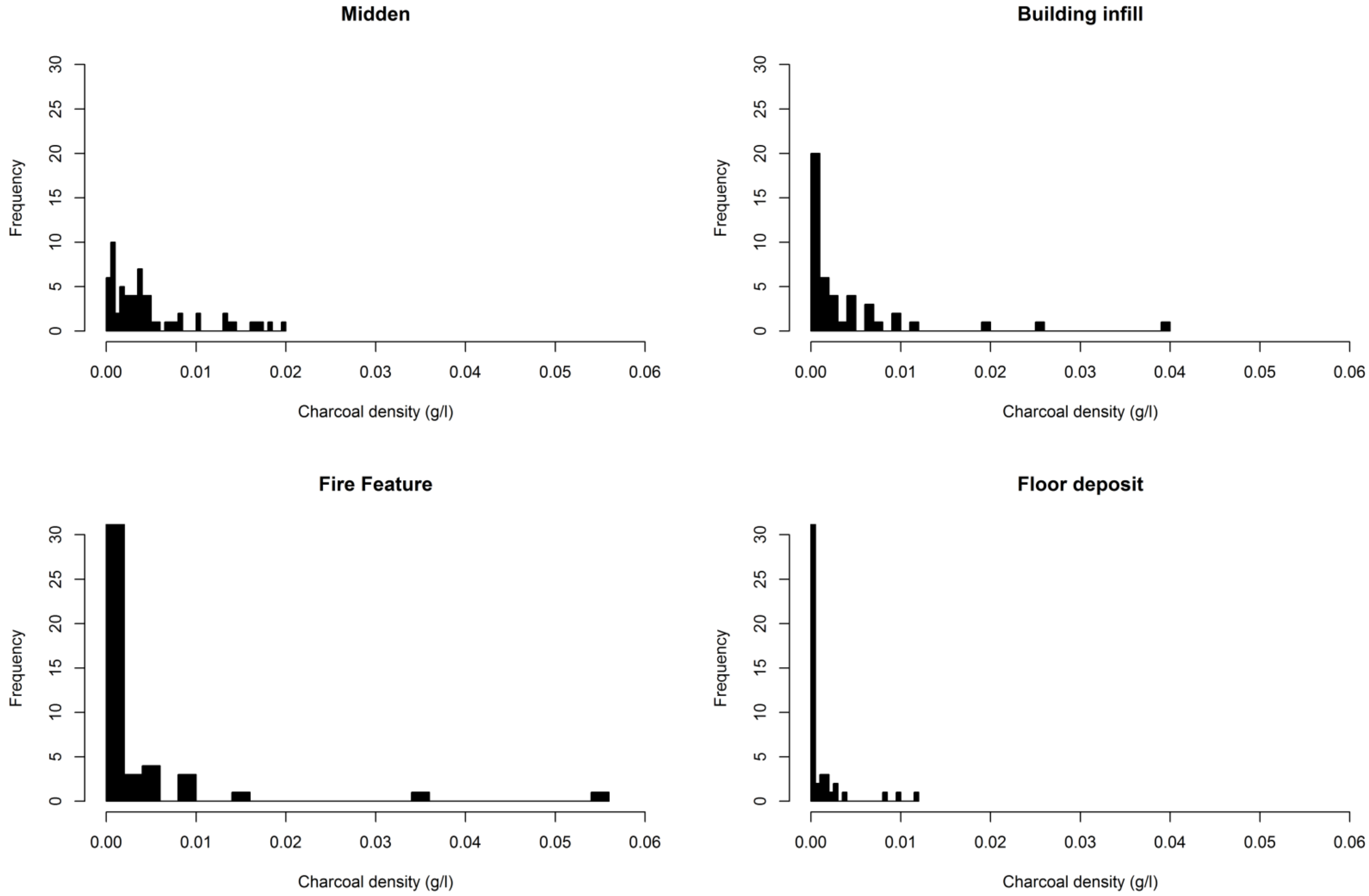


Figure 5.35: Distribution of wood charcoal density (g/l) for different context types at Boncuklu.

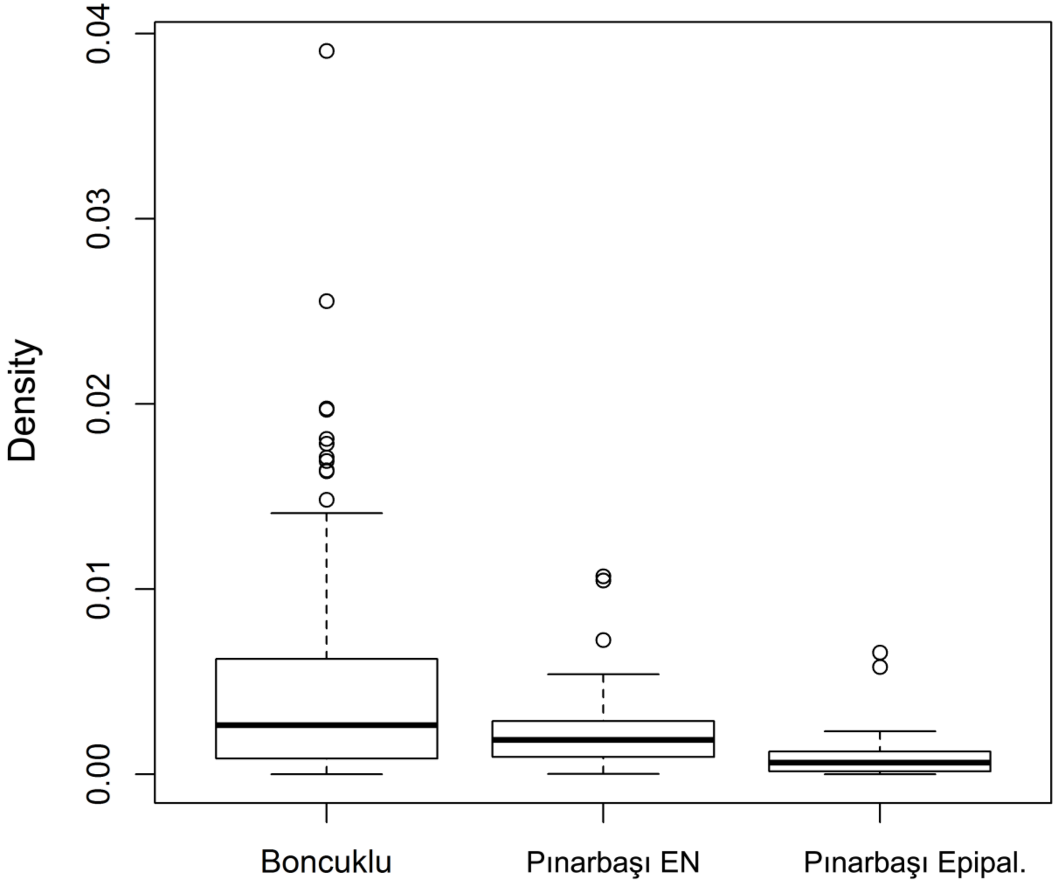


Figure 5.36: Boxplots of wood charcoal density (g/l) from dispersed contexts; Boncuklu, Pınarbaşı 9th millennia and Epipalaeolithic.

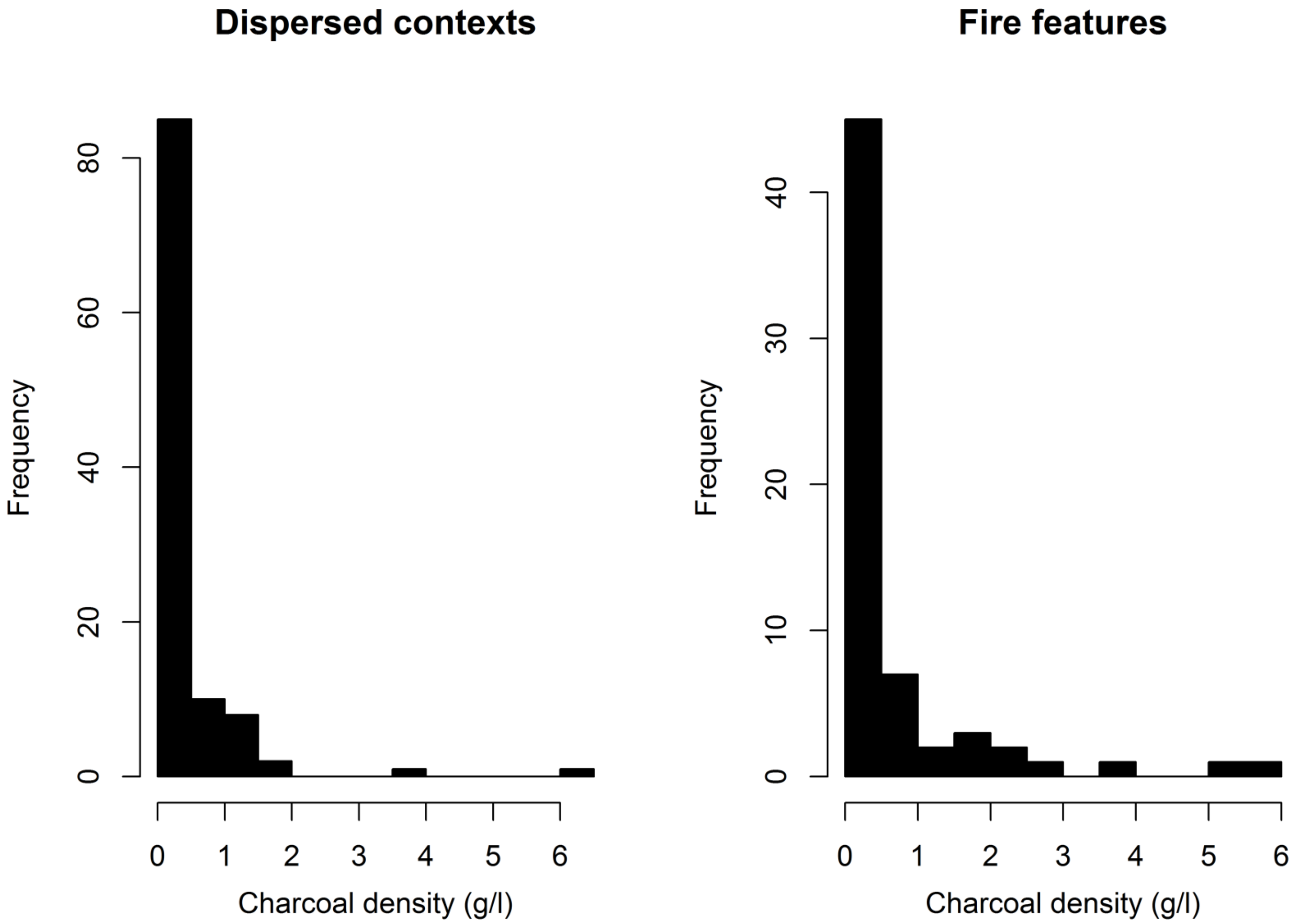


Figure 5.37: Distribution of wood charcoal density (g/l) in dispersed contexts and fire features at Çatalhöyük.

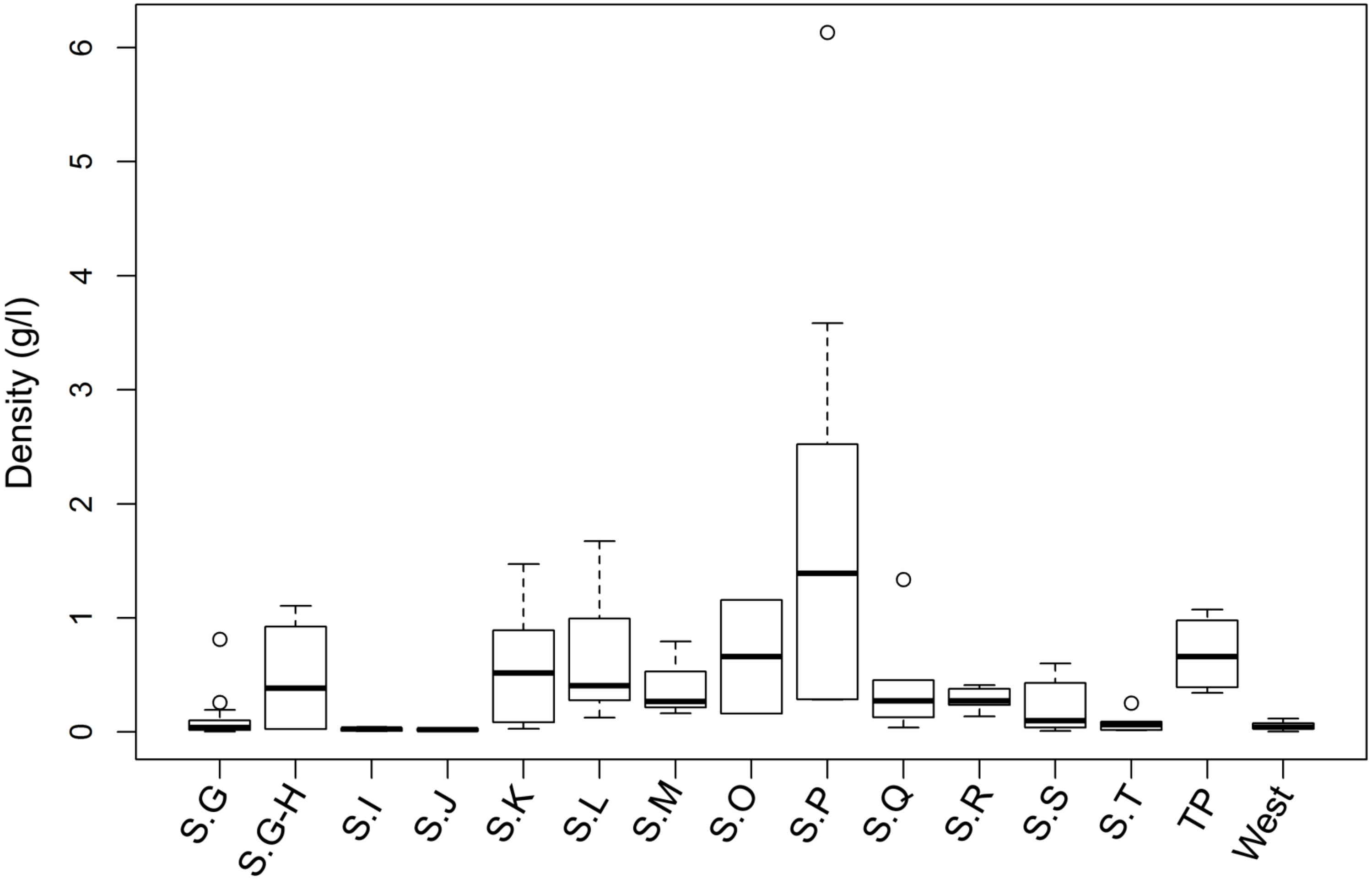


Figure 5.38: Boxplots of wood charcoal density (g/l) from dispersed contexts for each phase at Çatalhöyük.

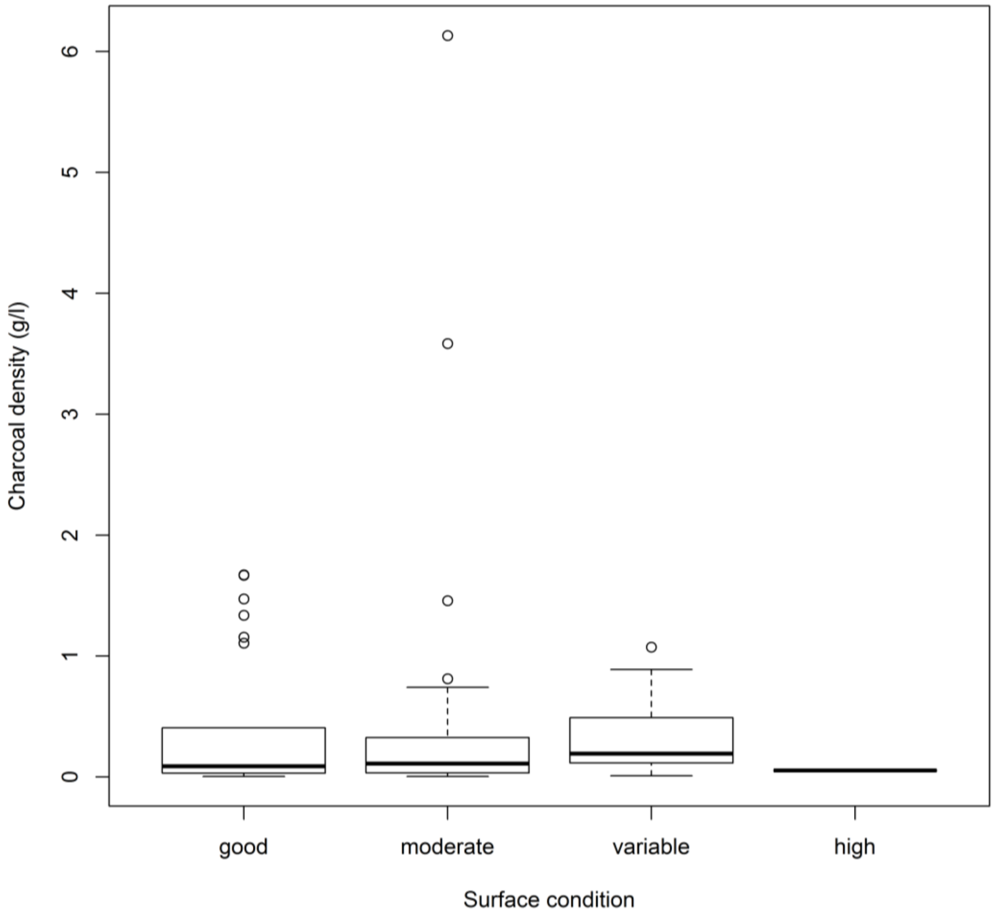


Figure 5.39: Comparison of wood charcoal density (g/l) from dispersed contexts at Çatalhöyük according to surface condition indicated by preservation state of faunal remains.

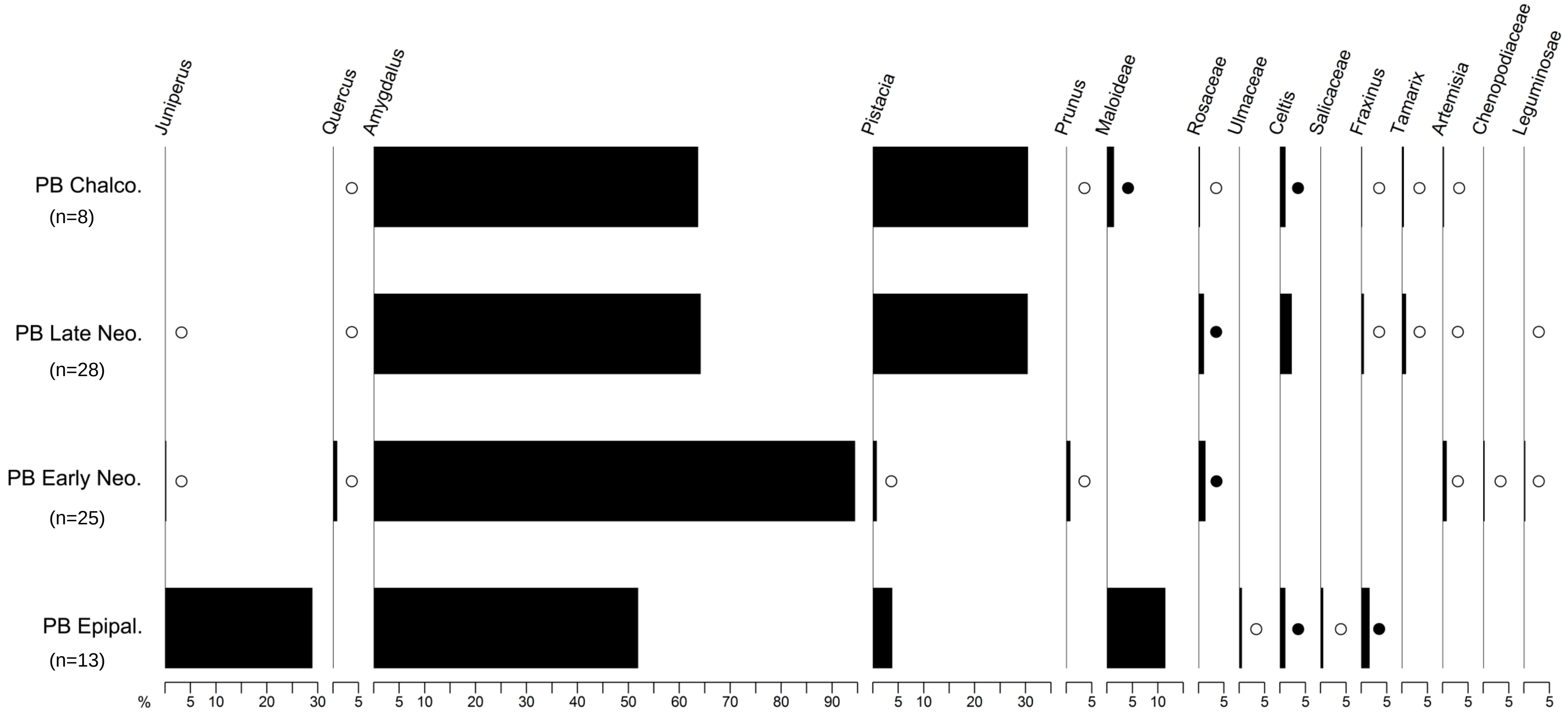


Figure 5.40: Anthracological diagram from all sampled phases at Pınarbaşı (dispersed contexts) (dark dots represent fragment counts <2%, white circles fragment counts <1%). (n=number of units/contexts, see also Table 5.16)

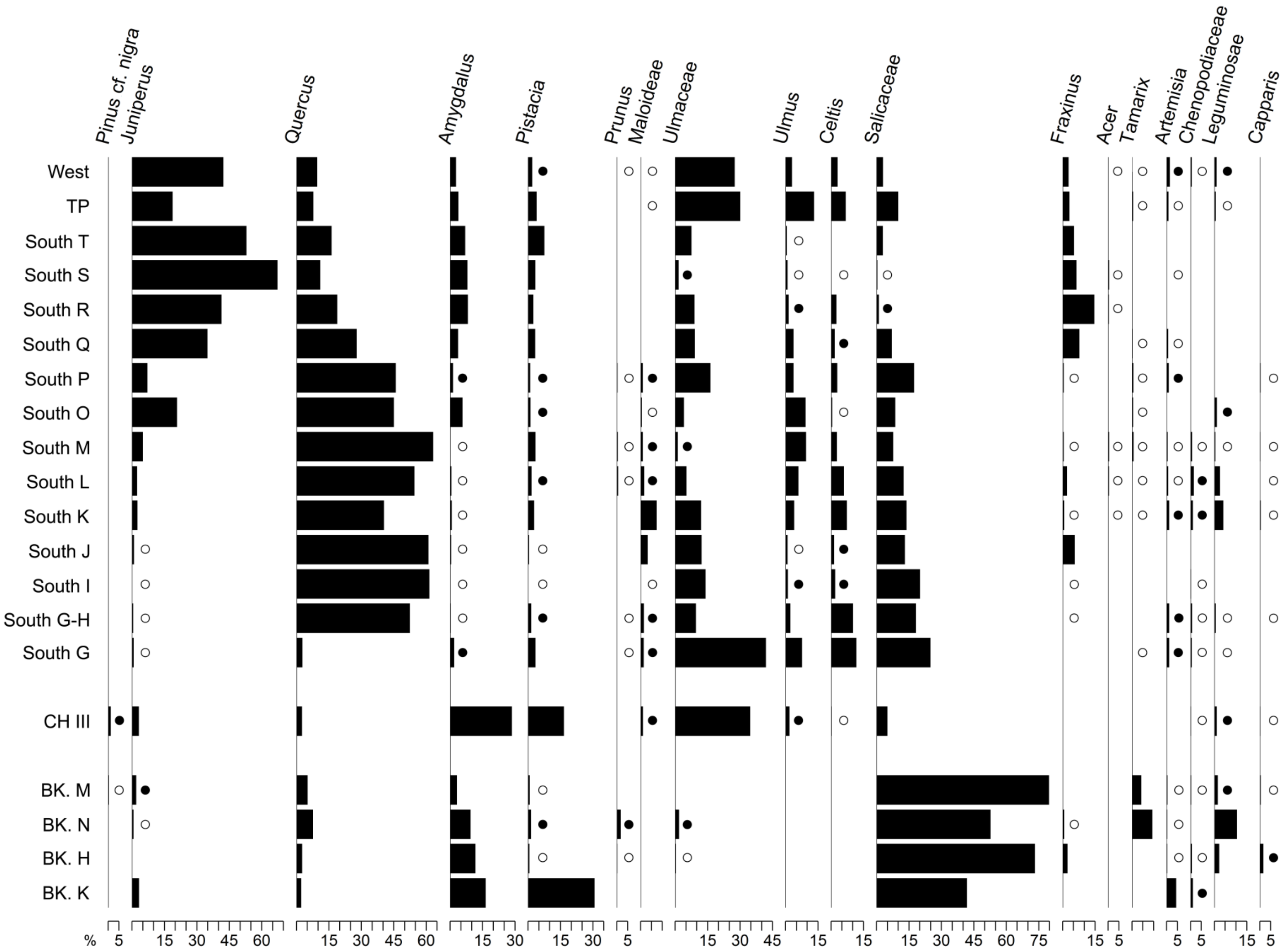


Figure 5.41: Anthracological diagram from all sampled phases at Boncuklu, Can Hasan III and Çatalhöyük East and West mounds (dispersed contexts) (dark dots represent fragment counts <2%, white circles fragment counts <1%). (for n=number of units/contexts analysed in each phase see Table 5.16)

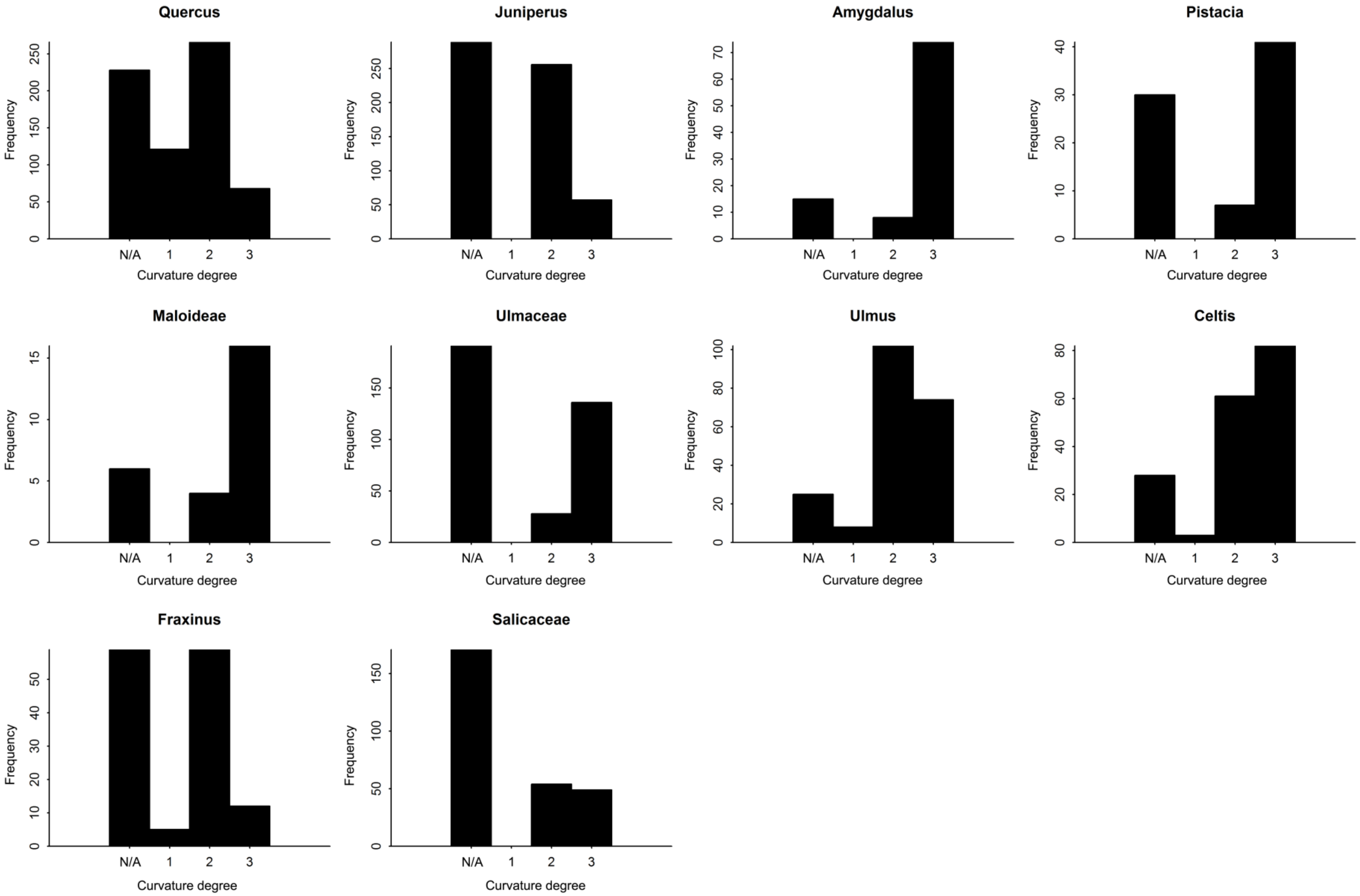


Figure 5.42: Distribution of Curve Degree (CD) classes in midden contexts for different taxa at Çatalhöyük.
N/A: Indeterminate, 1: CD1 (weakly curved), 2: CD2 (moderately curved), 3: CD3 (strongly curved)

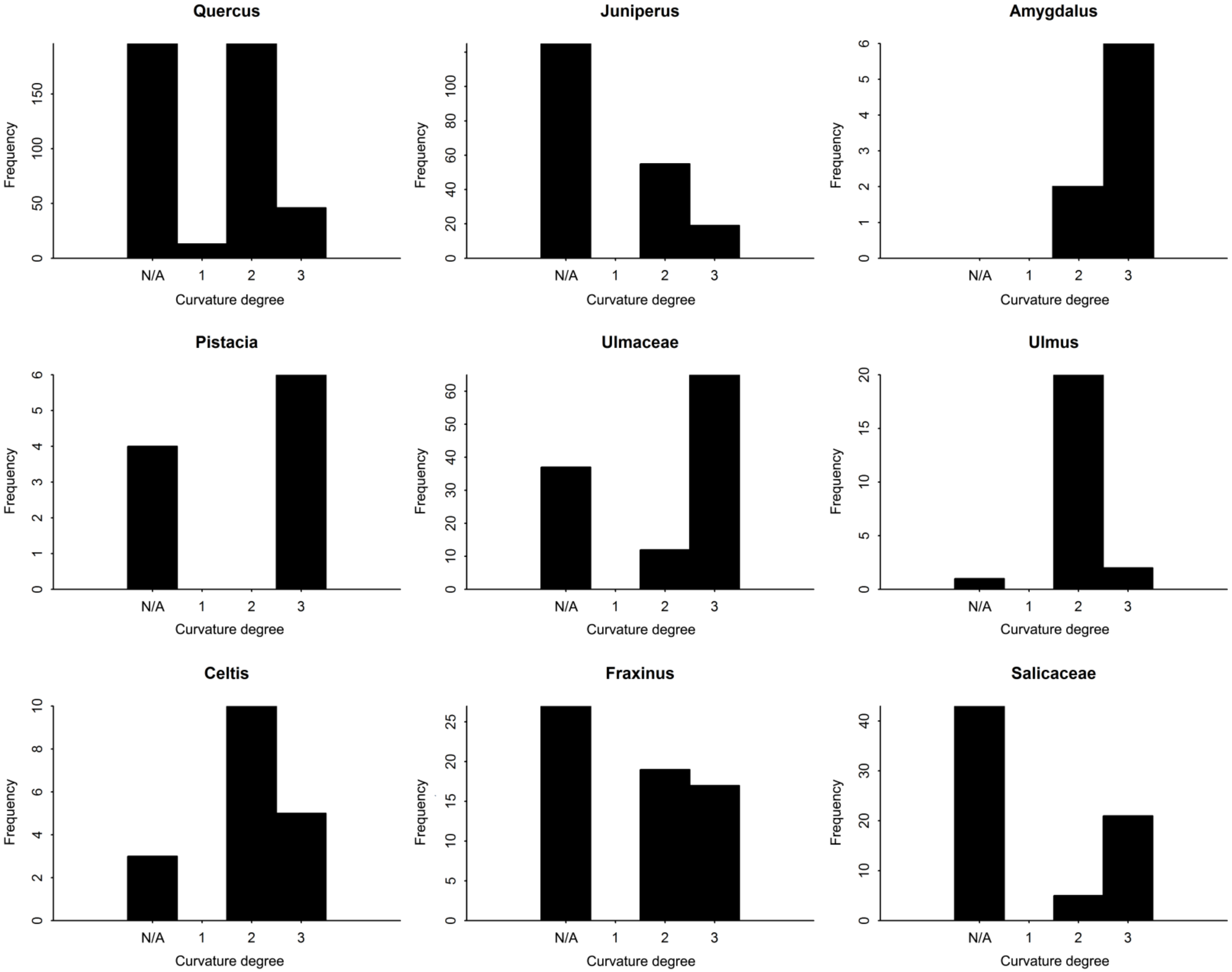


Figure 5.43: Distribution of Curve Degree (CD) classes in fire features for different taxa at Çatalhöyük.
N/A: Indeterminate, 1: CD1 (weakly curved), 2: CD2 (moderately curved), 3: CD3 (strongly curved).

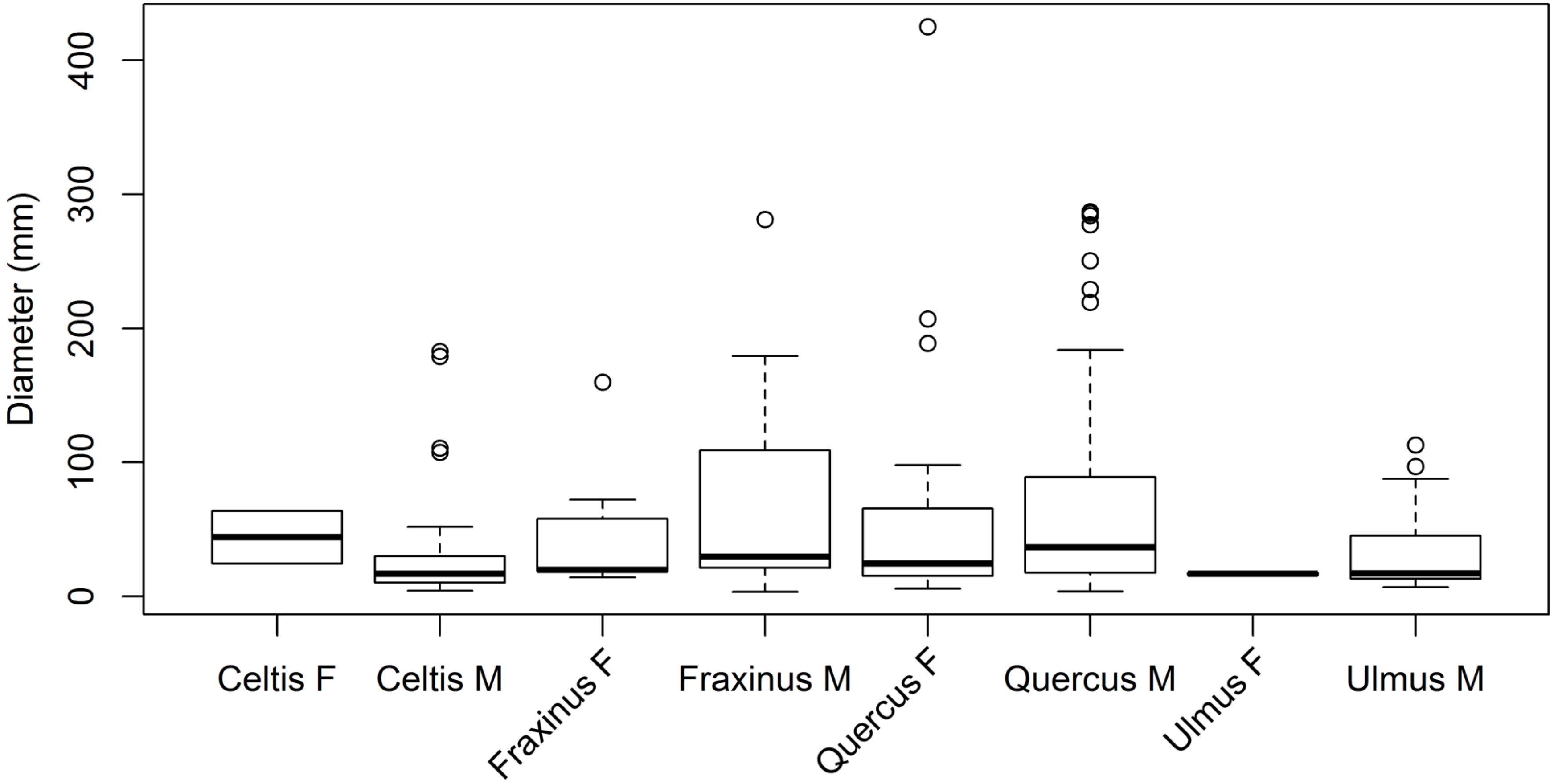


Figure 5.44: Boxplots of diameter measurements for each taxon at Çatalhöyük from middens and fire features. (M: midden contexts, F: fire features.)

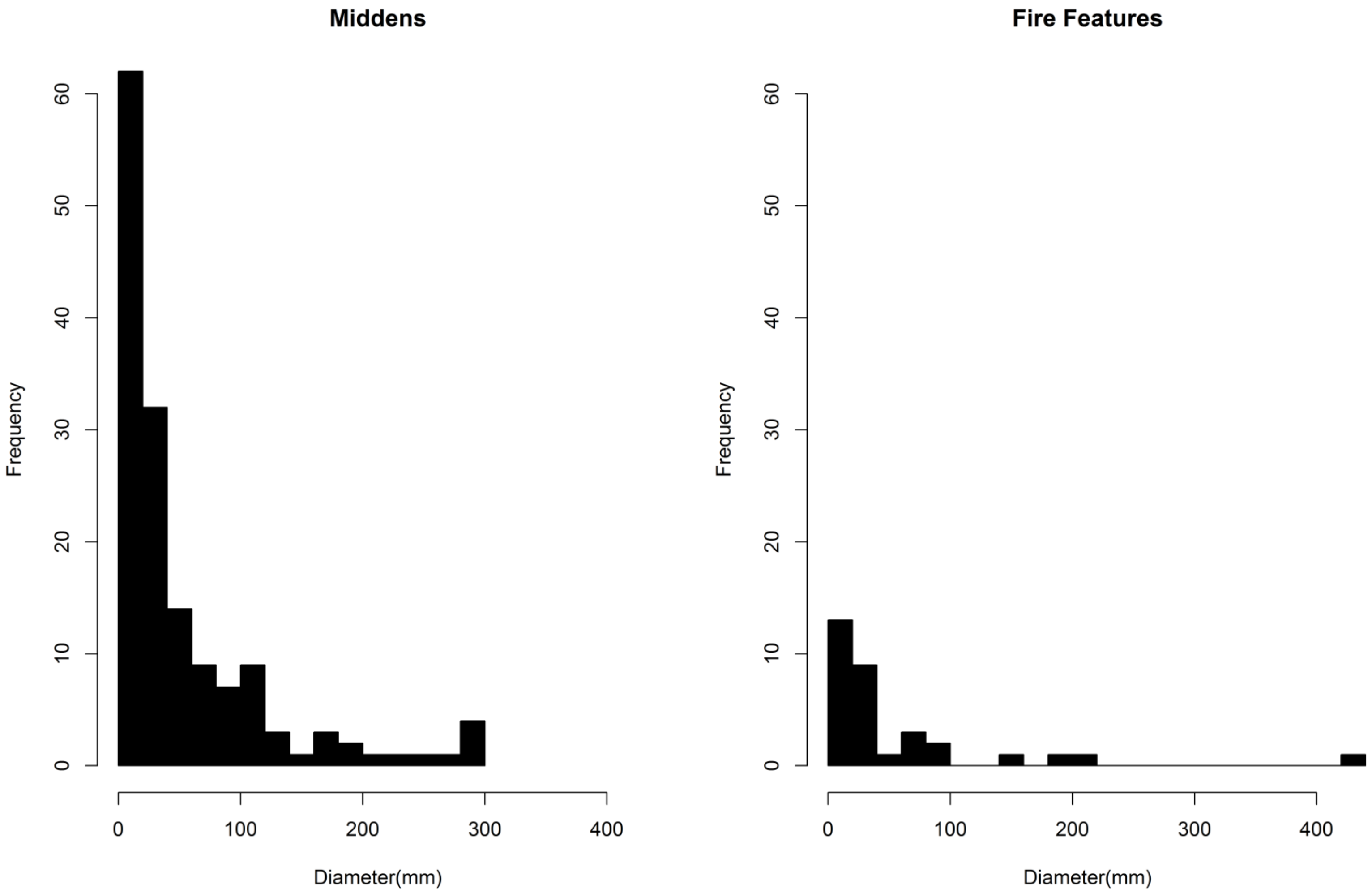


Figure 5.45: Distributions of diameter measurements from middens and fire features at Çatalhöyük.

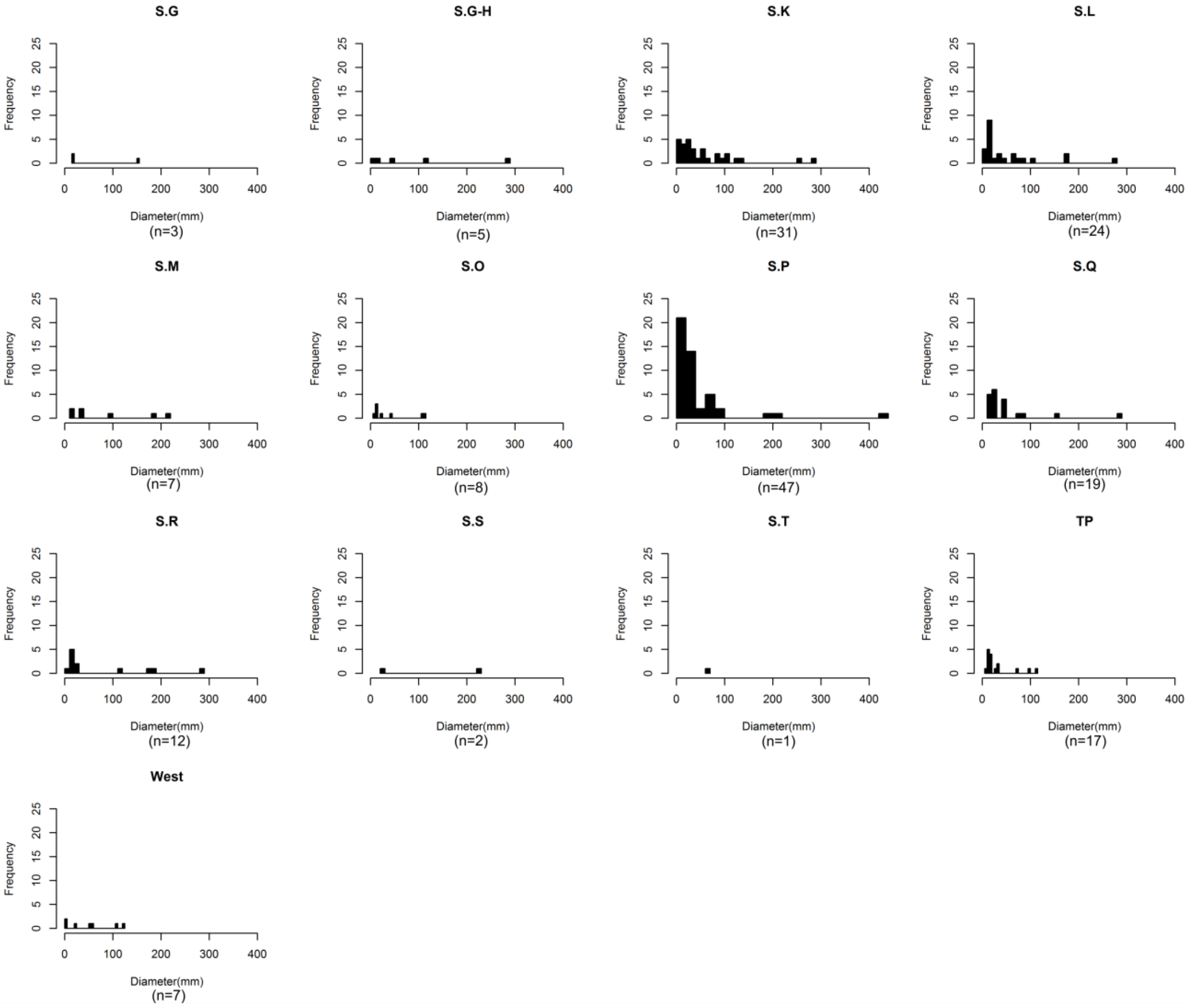


Figure 5.46: Distributions of diameter measurements for all taxa, per phase at Çatalhöyük. (n: number of measurements)

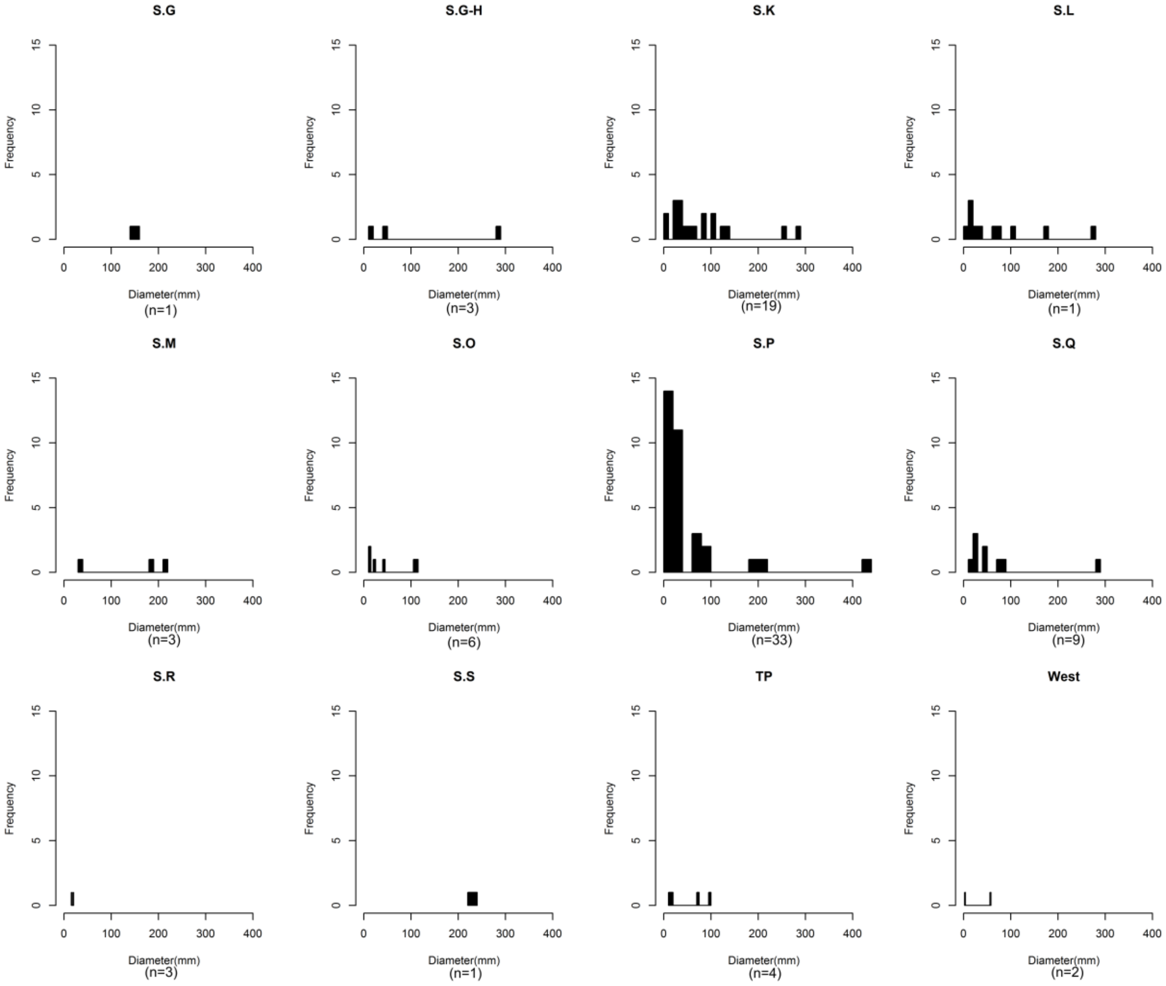


Figure 5.47: Distributions of diameter measurements *Quercus*, per phase at Çatalhöyük. (n: number of measurements)

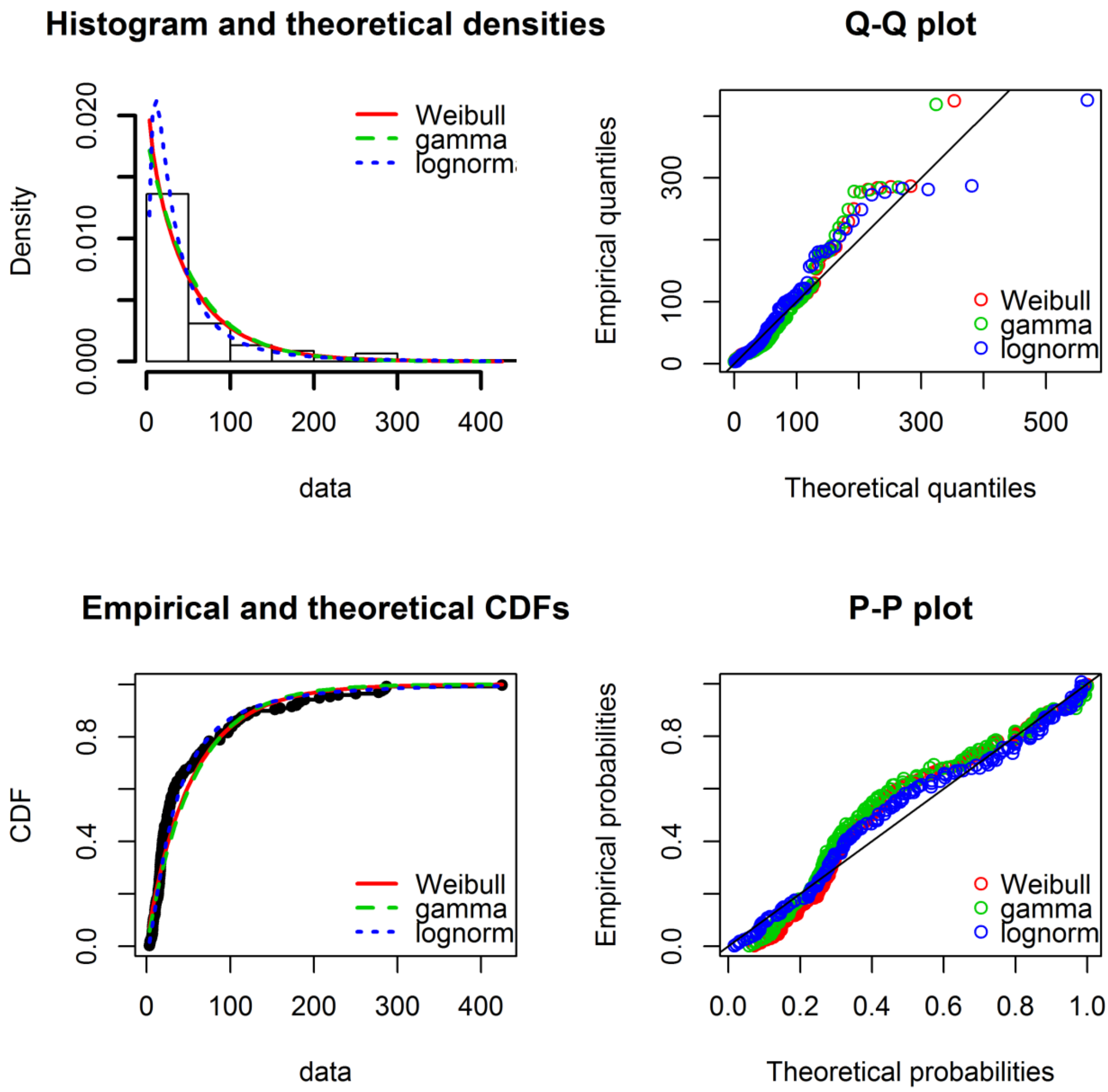


Figure 5.48a: Distribution of diameter measurements, goodness of fit plots (density, Q-Q, CDF, P-P) for lognormal, gamma and Weibull distribution.

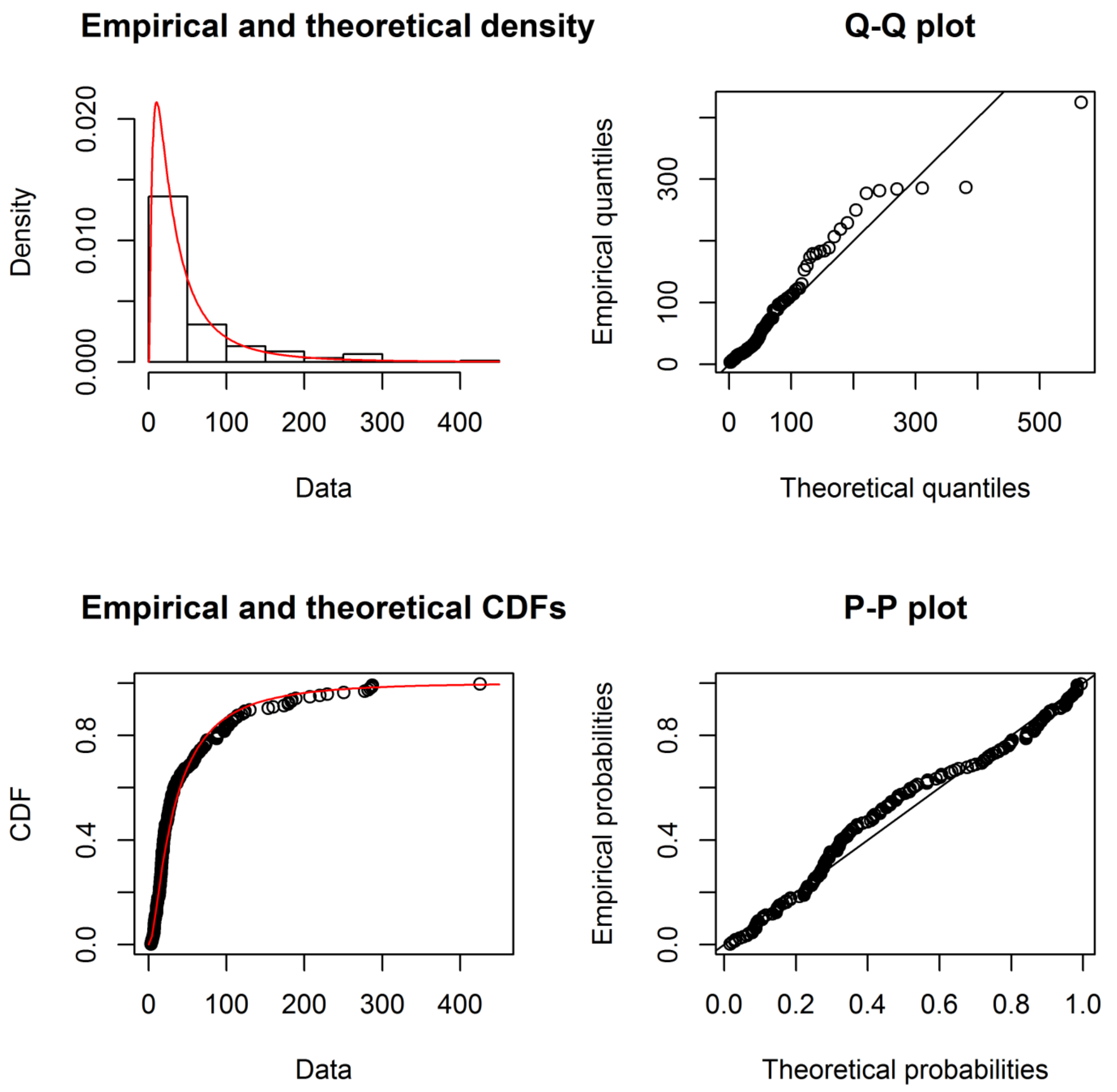


Figure 5.48b: Fit of lognormal distribution (theoretical) on diameter measurements from Çatalhöyük (empirical).

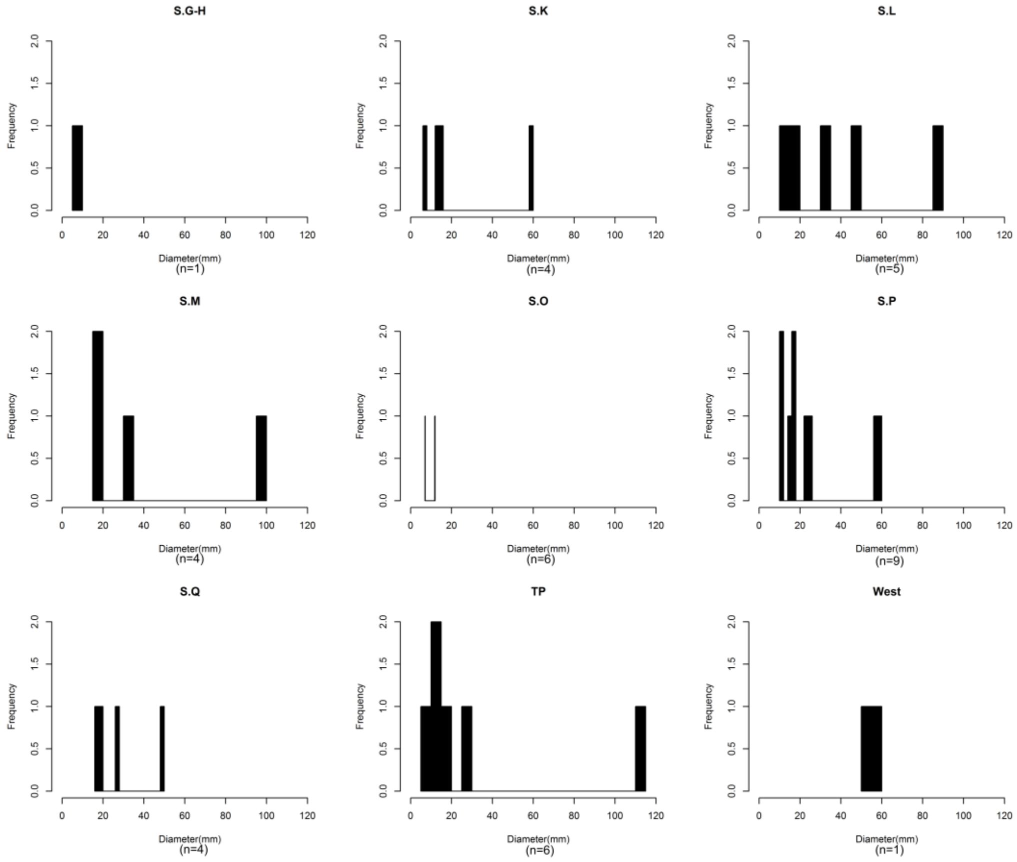


Figure 5.49: Distributions of diameter measurements for *Ulmus*, per phase at Çatalhöyük. (n: number of measurements)

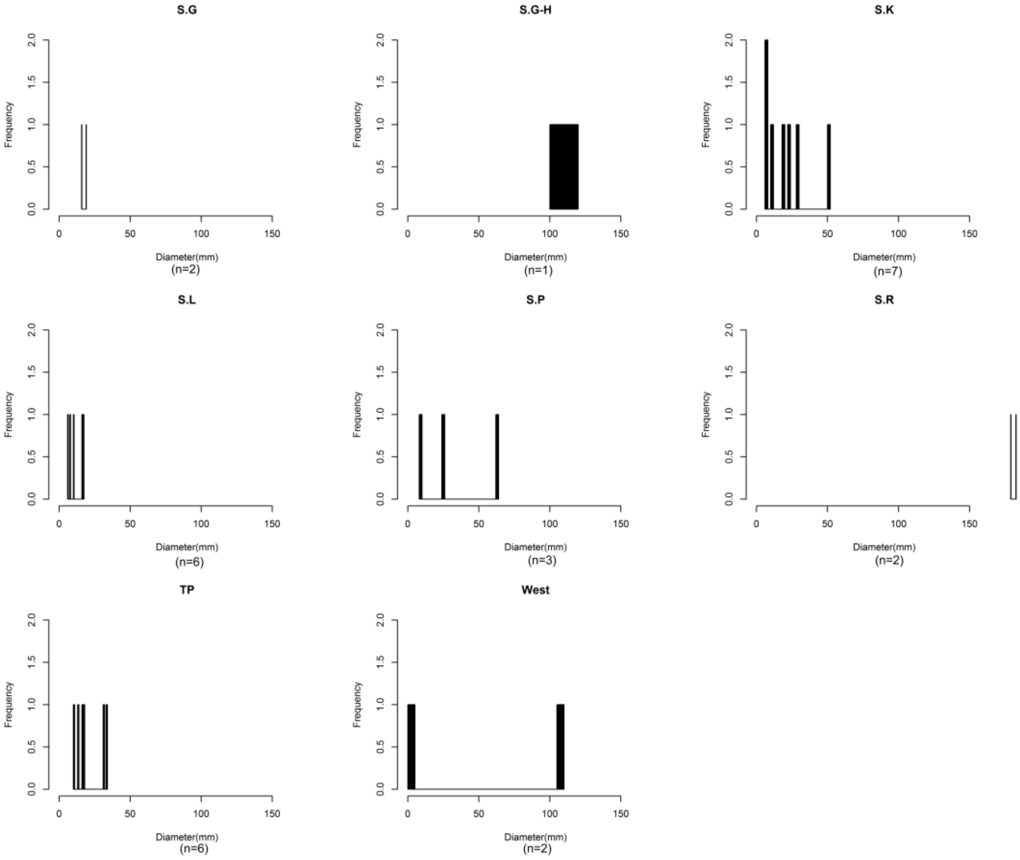


Figure 5.50: Distributions of diameter measurements for *Celtis*, per phase at Çatalhöyük. (n: number of measurements)

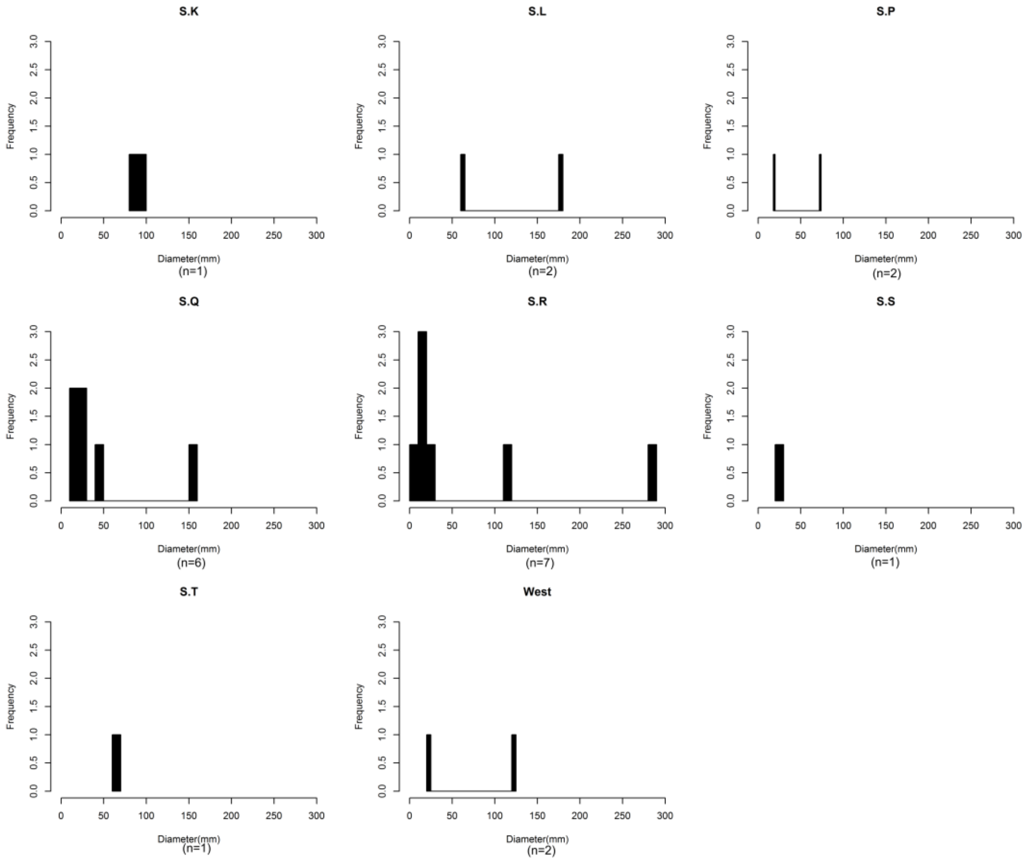


Figure 5.51: Distributions of diameter measurements for Fraxinus, per phase at Çatalhöyük. (n: number of measurements).

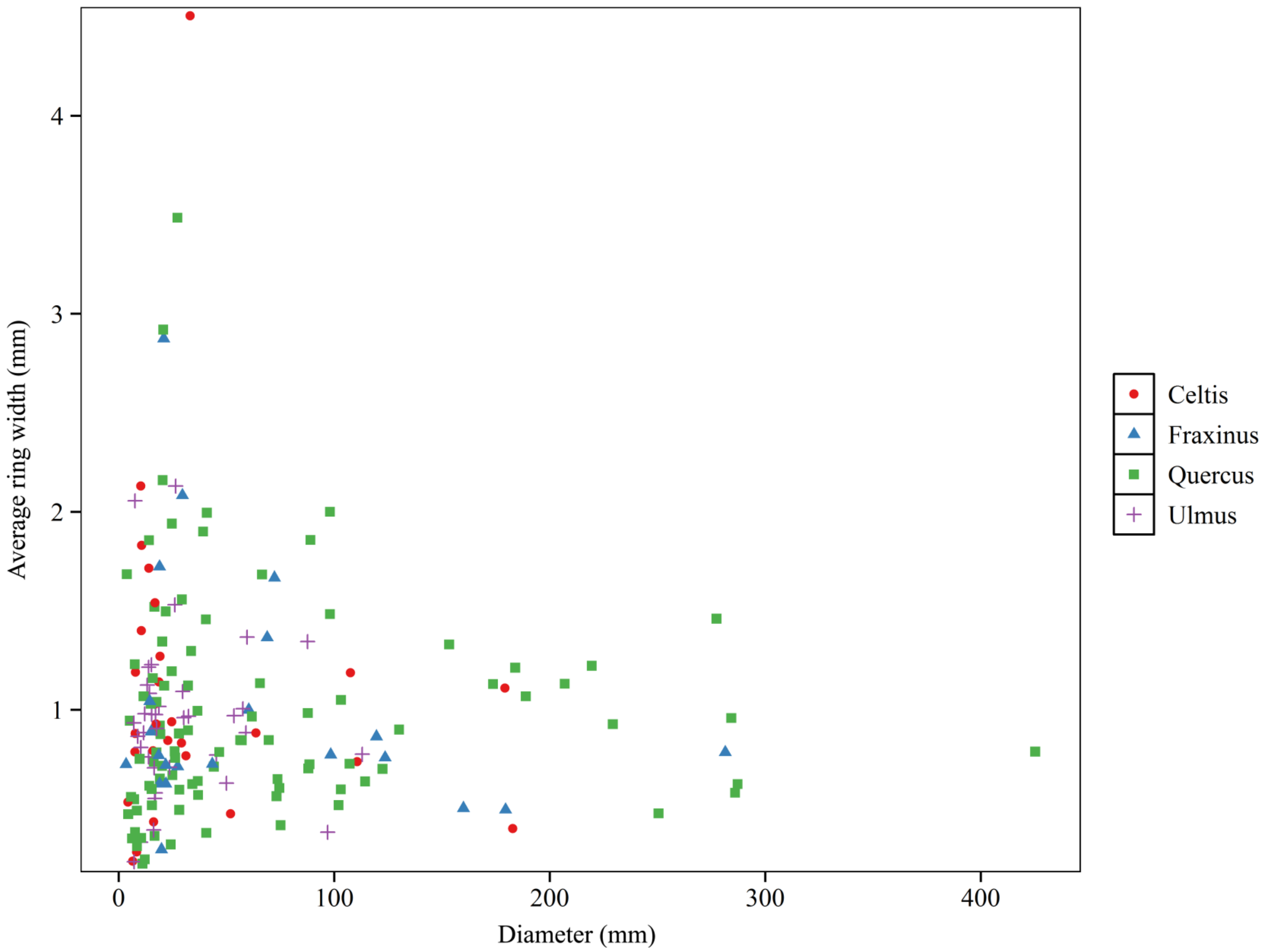


Figure 5.52: Scatter plot of average ring width and diameter measurements for each specimen from Çatalhöyük.

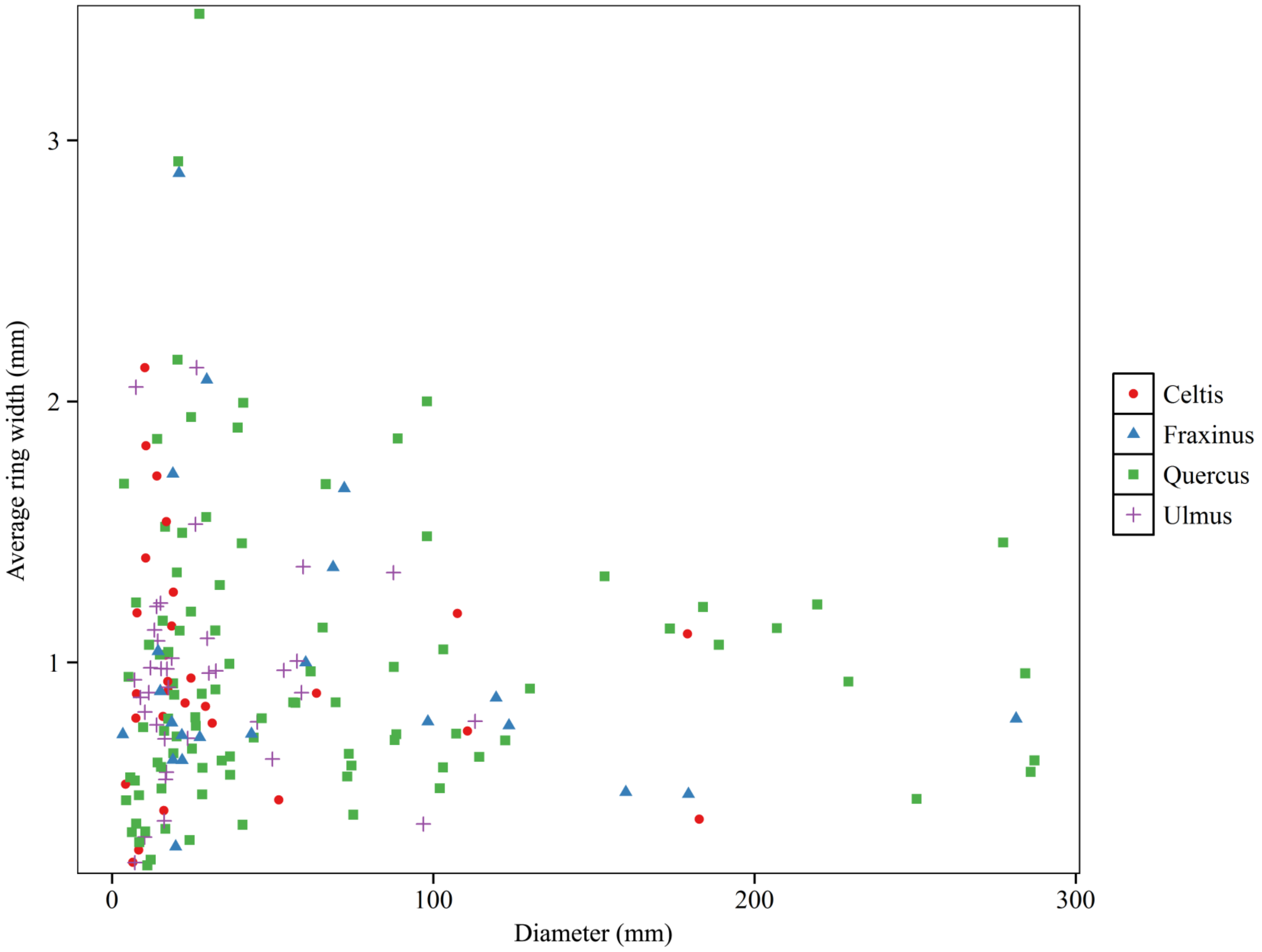


Figure 5.53: Scatter plot of average ring width and diameter measurements for each specimen from Çatalhöyük, with outlier removed.

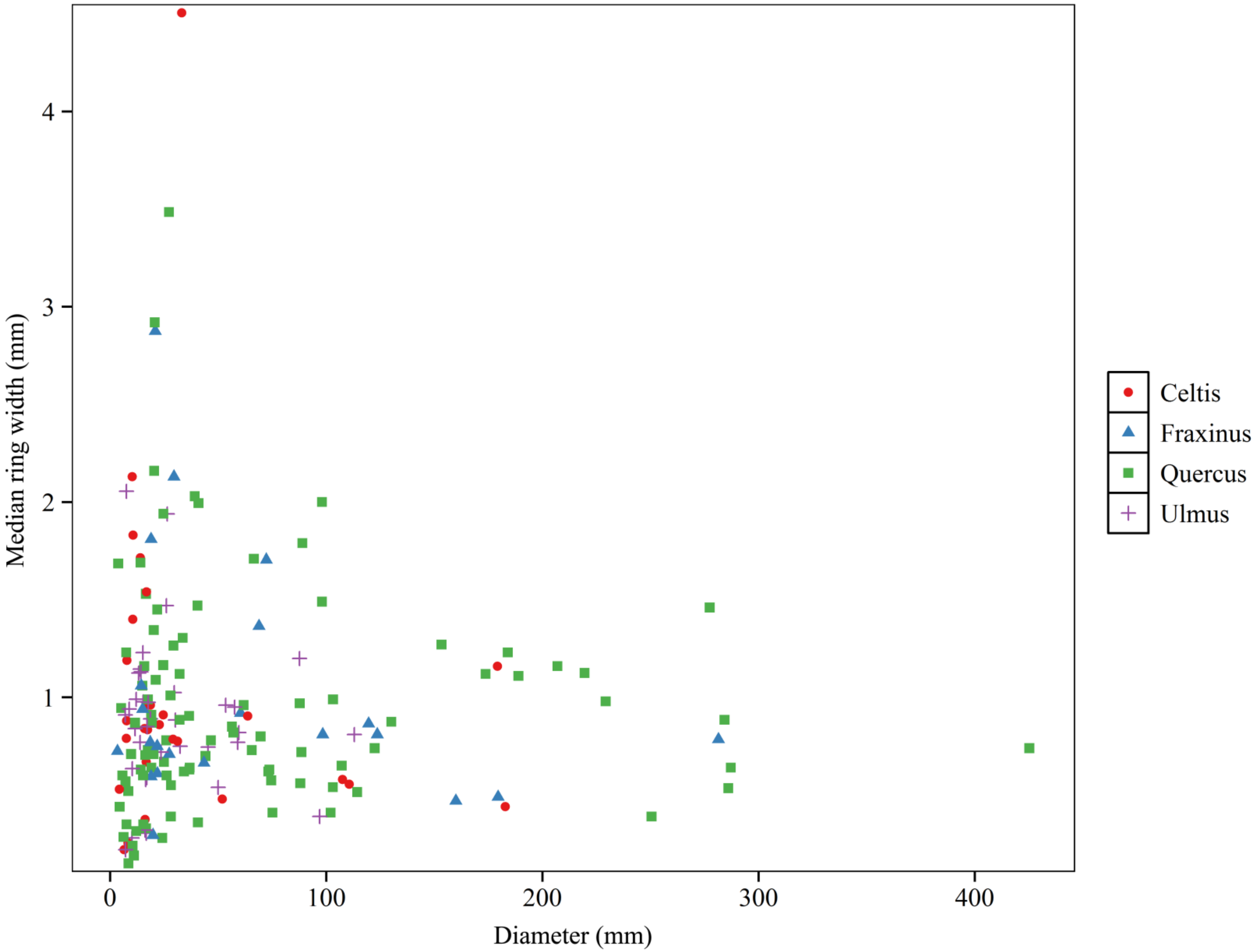


Figure 5.54: Scatter plot of median ring width and diameter measurements for each specimen from Çatalhöyük.

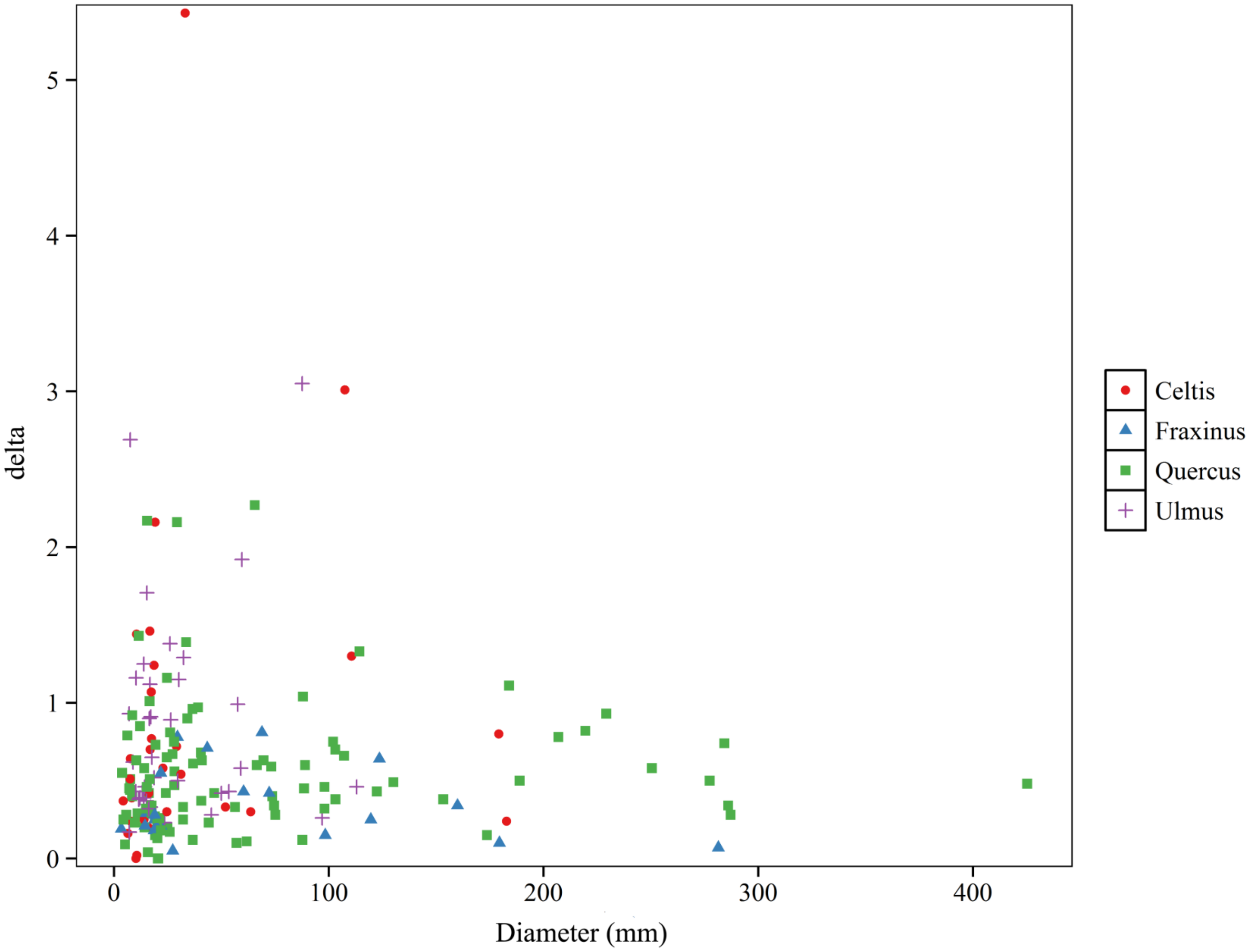


Figure 5.55: Scatter plot of delta ring width (:maximum-minimum) and diameter measurements for each specimen from Çatalhöyük.

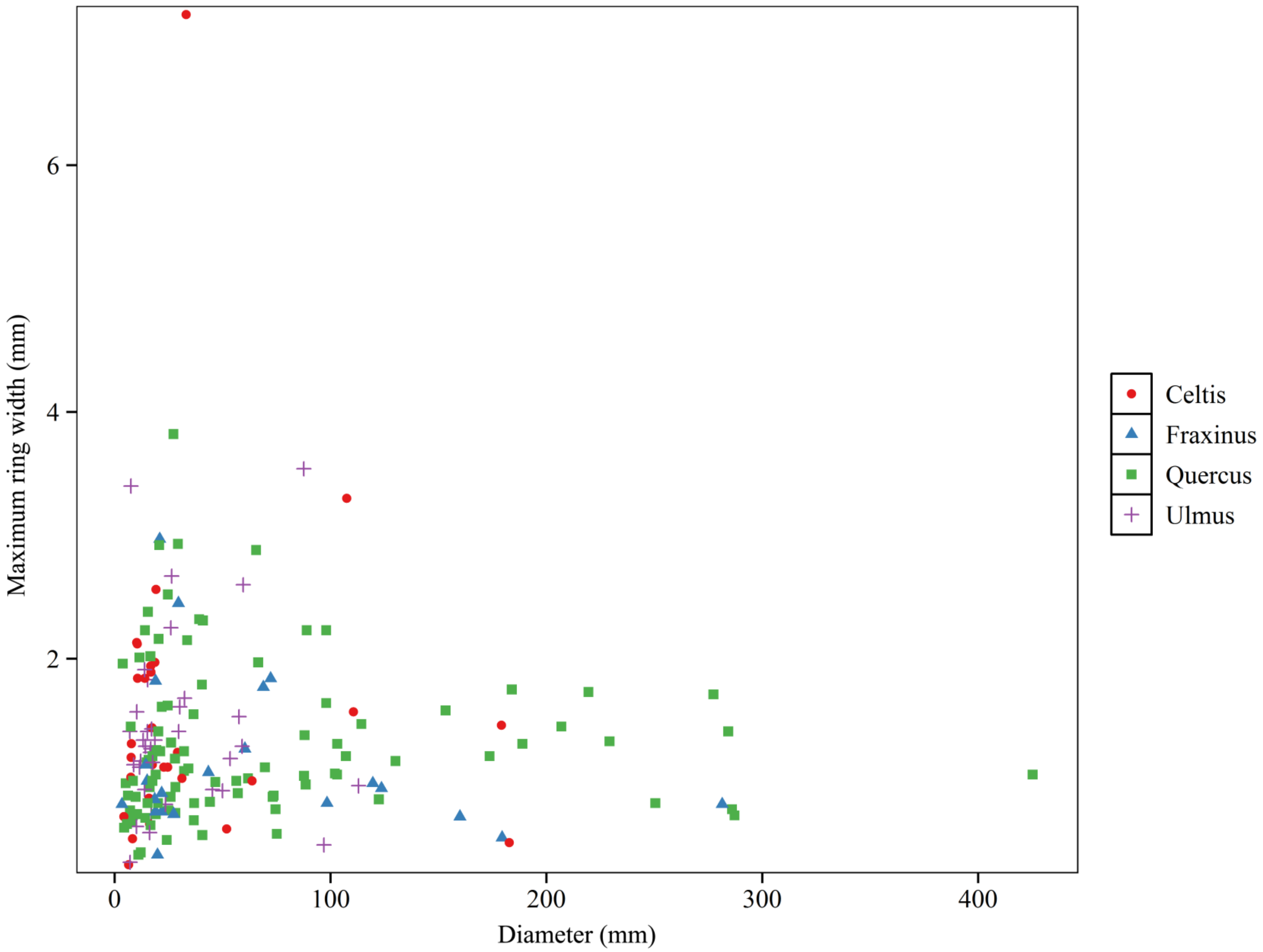


Figure 5.56: Scatter plot of maximum ring width and diameter measurements for each specimen from Çatalhöyük.

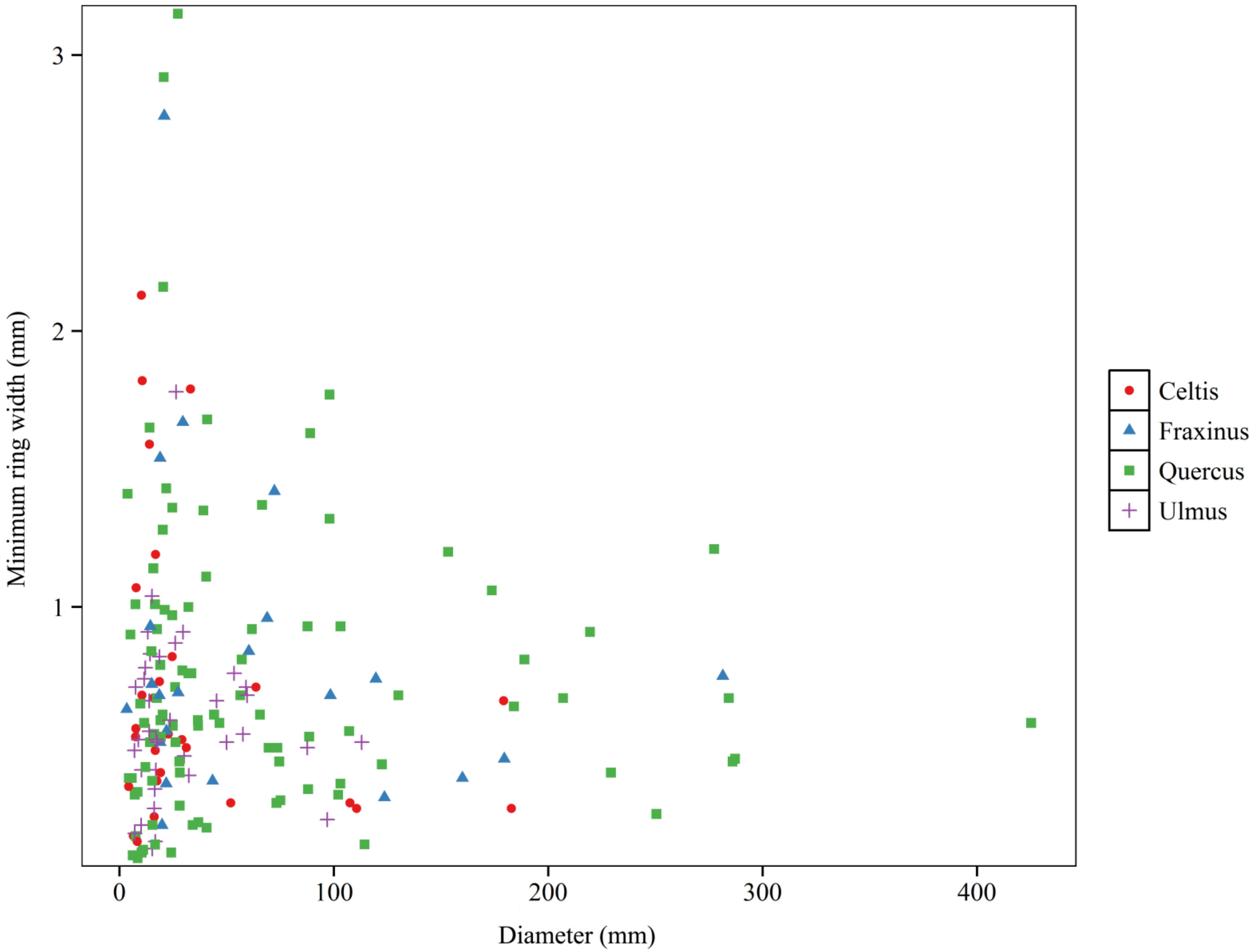


Figure 5.57: Scatter plot of minimum ring width and diameter measurements for each specimen from Çatalhöyük.

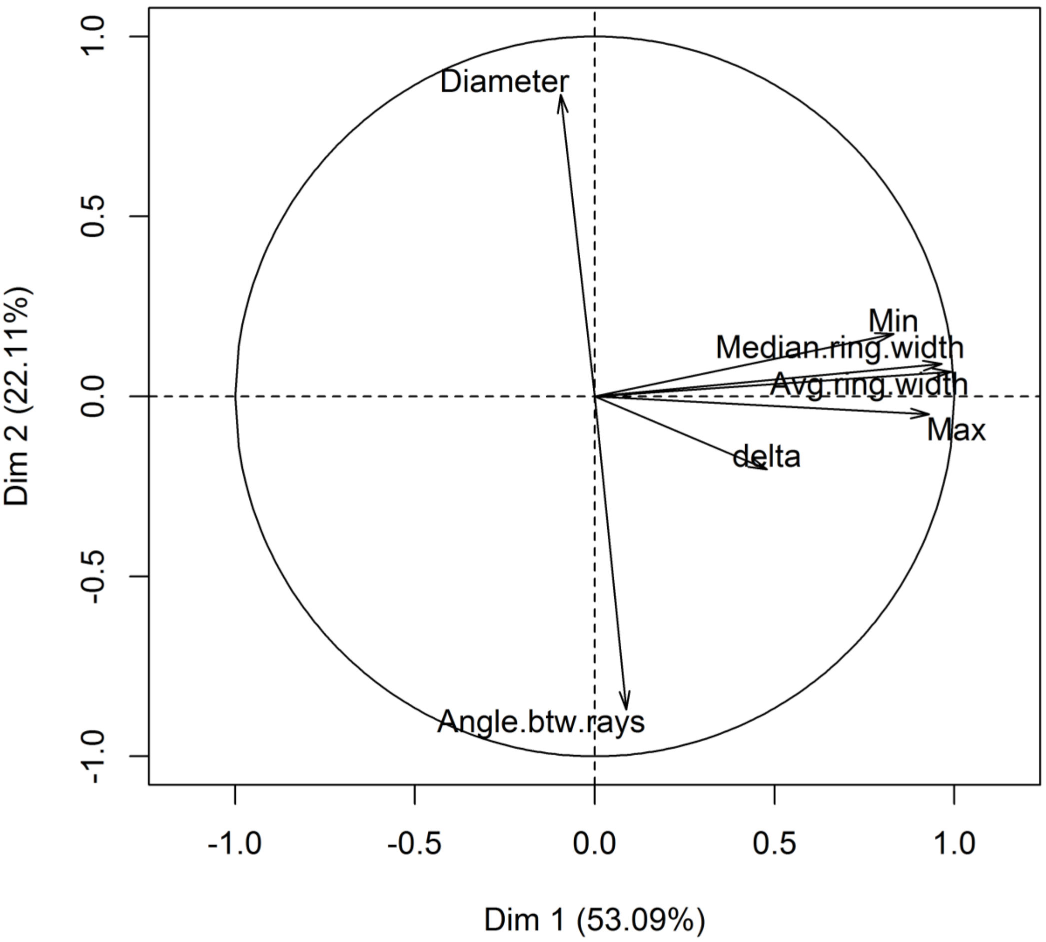


Figure 5.58: PCA with Diameter, angle between rays, average, median, minimum, maximum and delta ring width values; plot of dimensions 1 and 2.

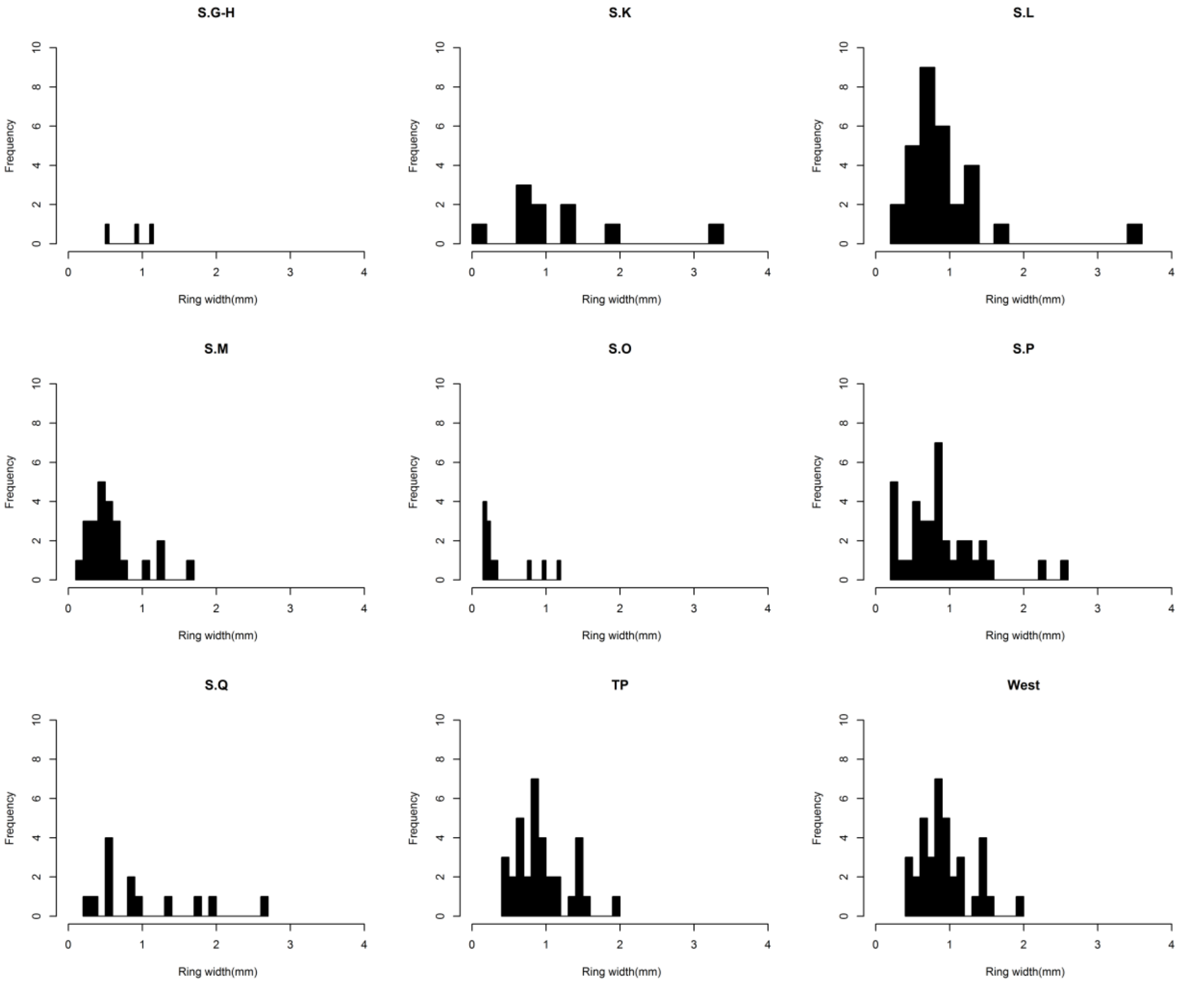


Figure 5.59: Distributions of ring width measurements for Ulmus, per phase at Çatalhöyük.

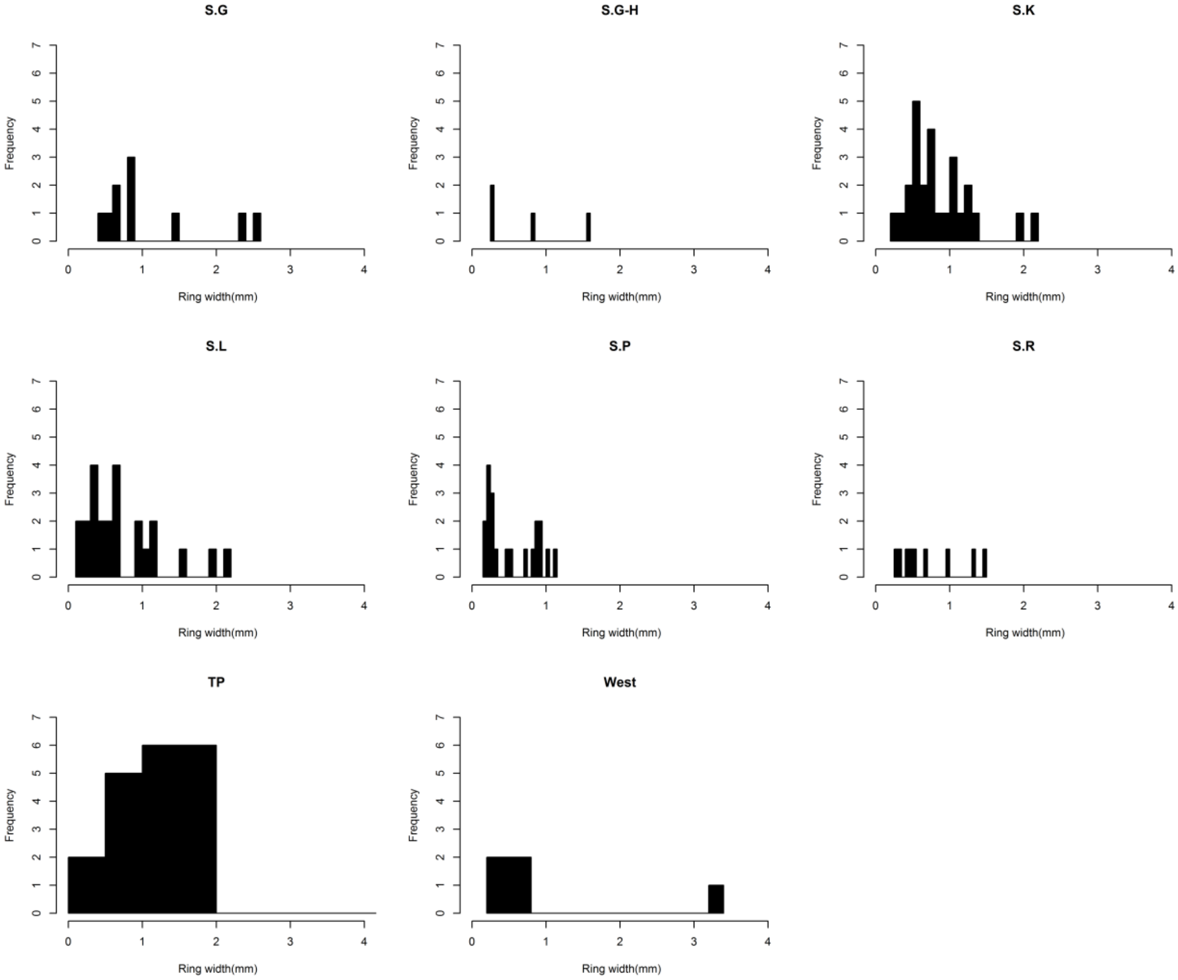
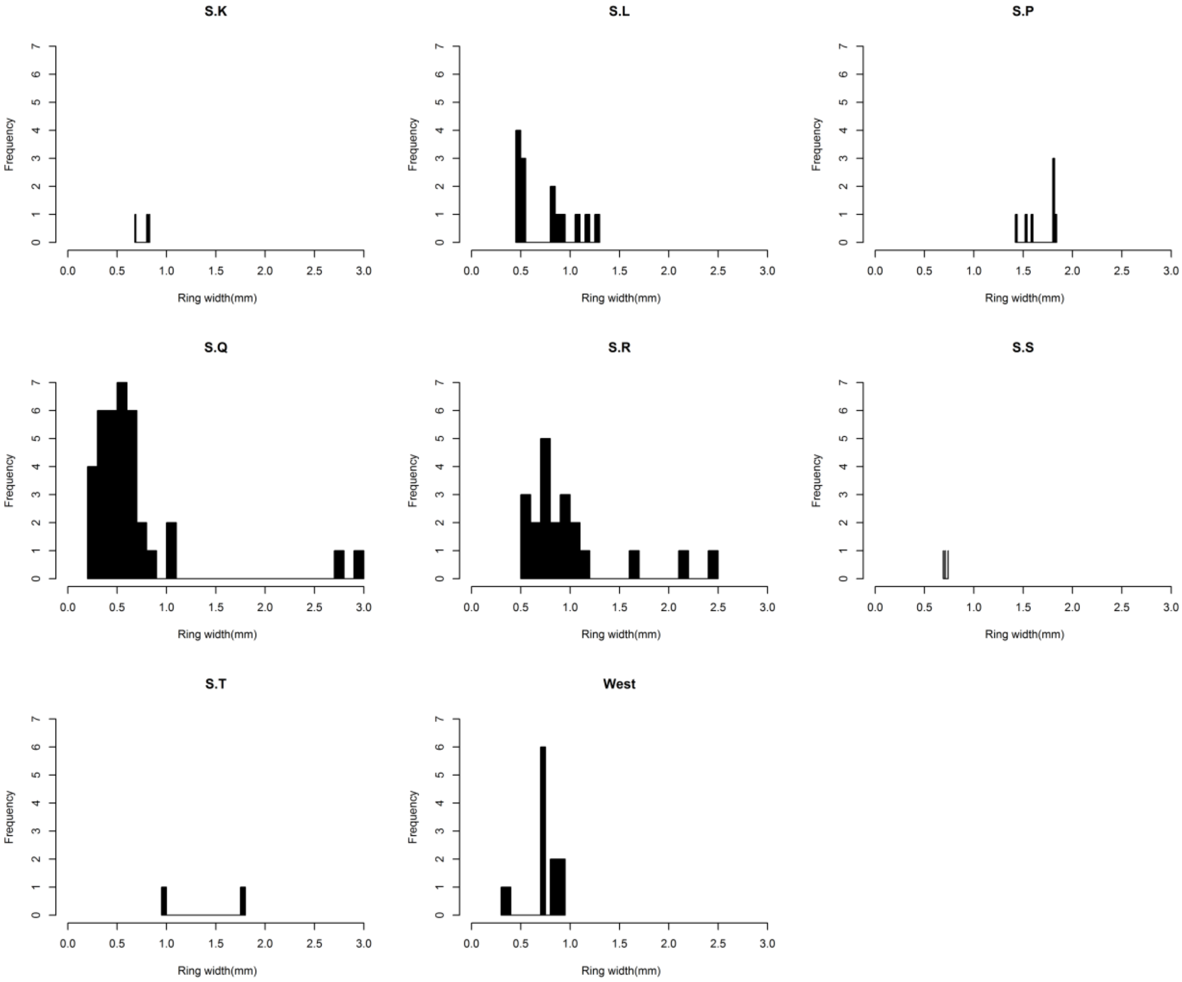


Figure 5.60: Distributions of ring width measurements for *Celtis*, per phase at Çatalhöyük.



S.K S.L S.P S.Q S.R S.S S.T West

Figure 5.61: Distributions of ring width measurements for *Fraxinus*, per phase at Çatalhöyük.

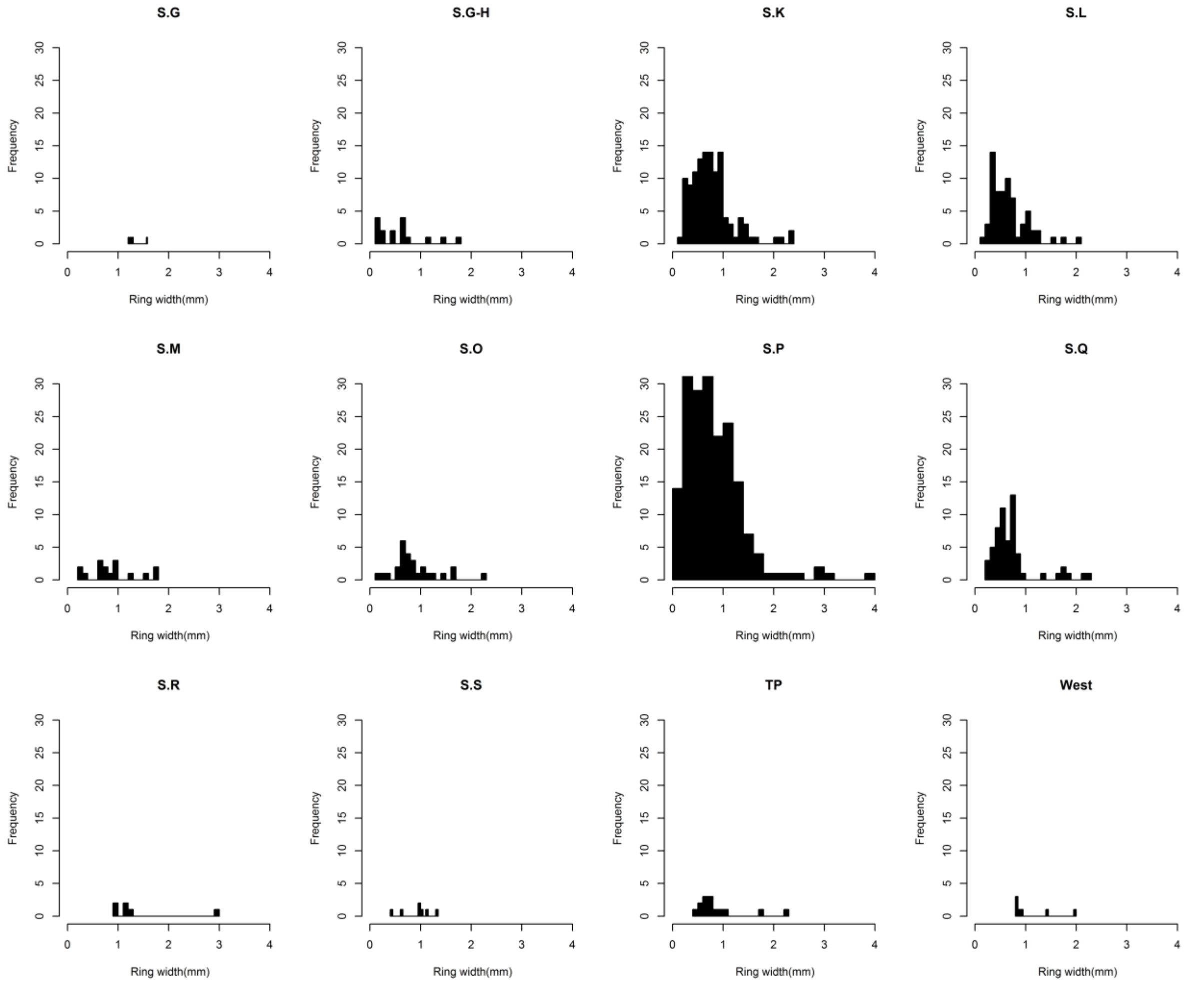


Figure 5.62: Distributions of ring width measurements for *Quercus*, per phase at Çatalhöyük.

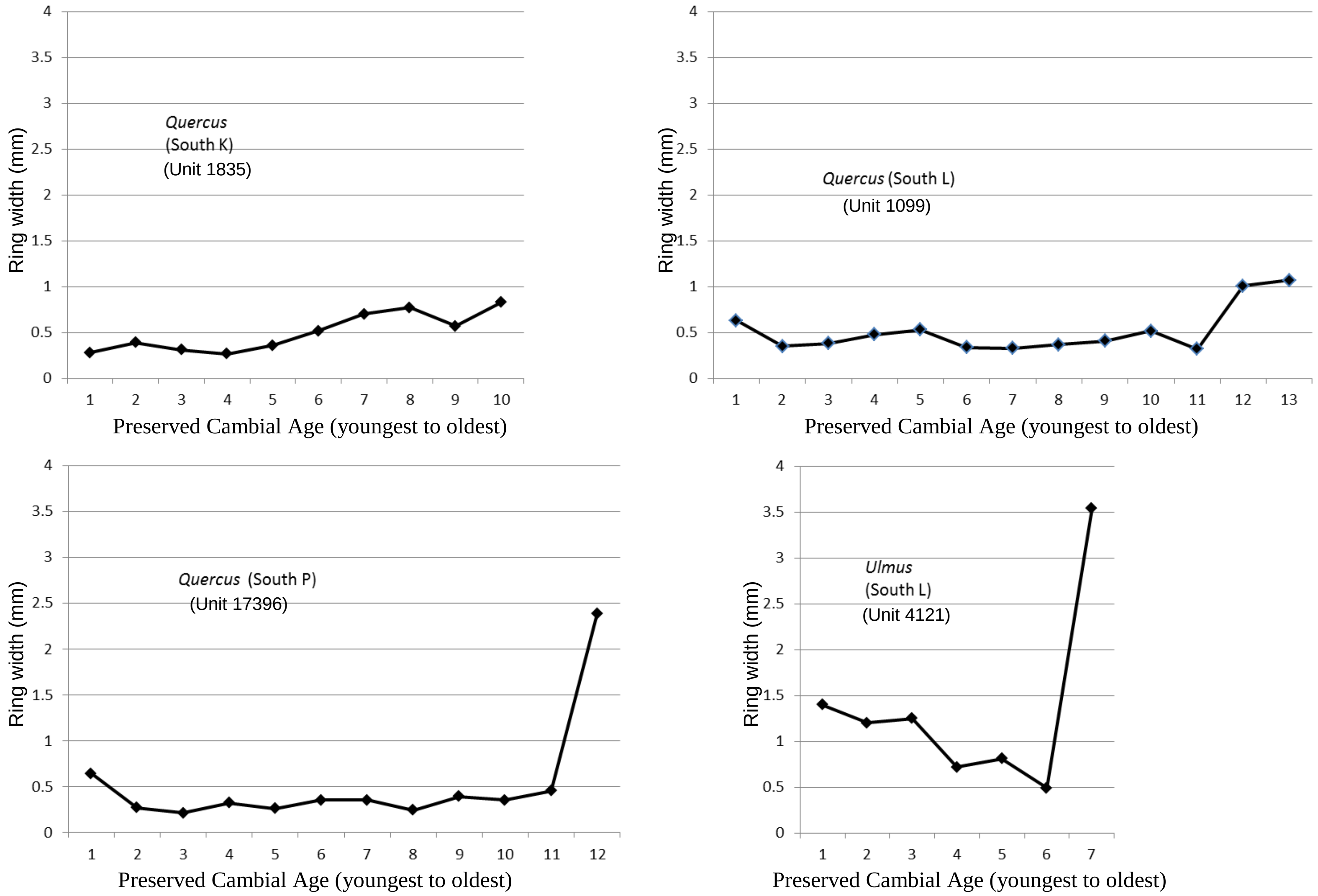


Figure 5.63: Growth ring width patterns in individual charcoal fragments. Ring width (mm) plotted against successive growth rings from the youngest preserved ring (1) to the oldest preserved ring in each specimen.

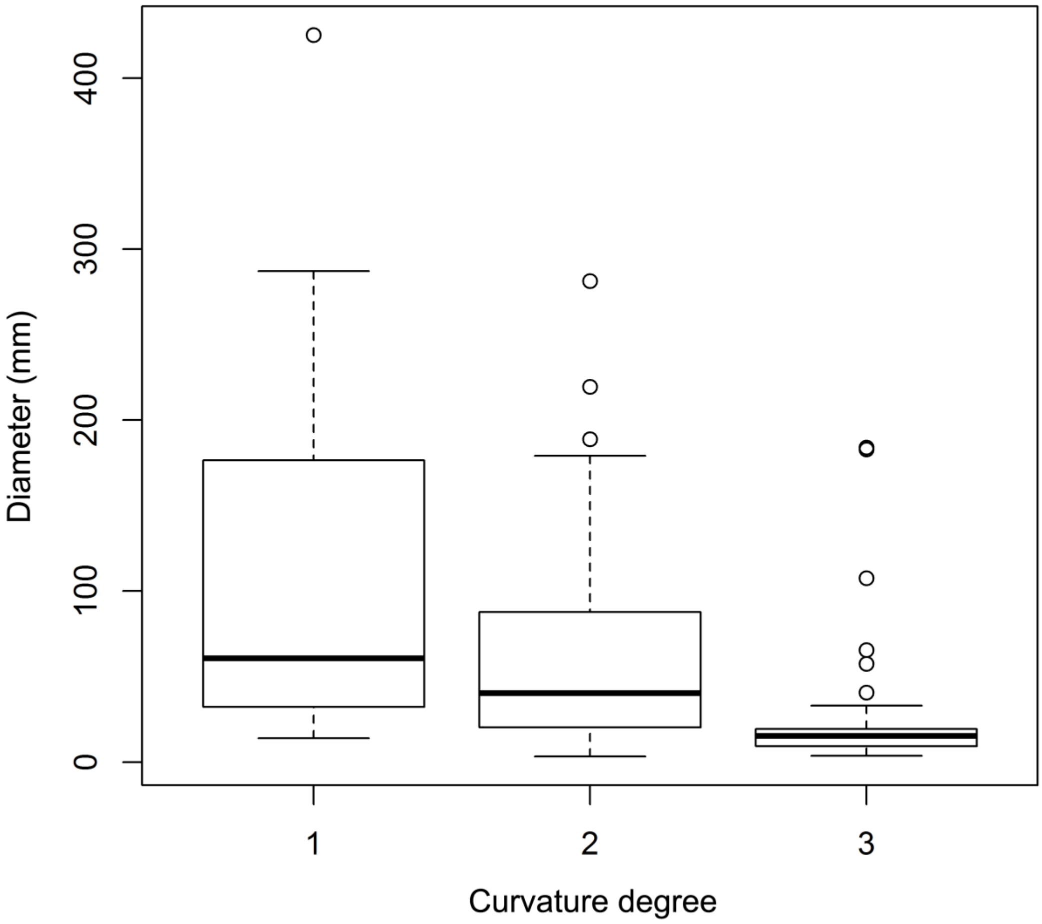


Figure 5.64: Boxplots of diameter measurements for specimens of different Curve Degree classes. (1: weakly curved, 2: moderately curved, 3: strongly curved).

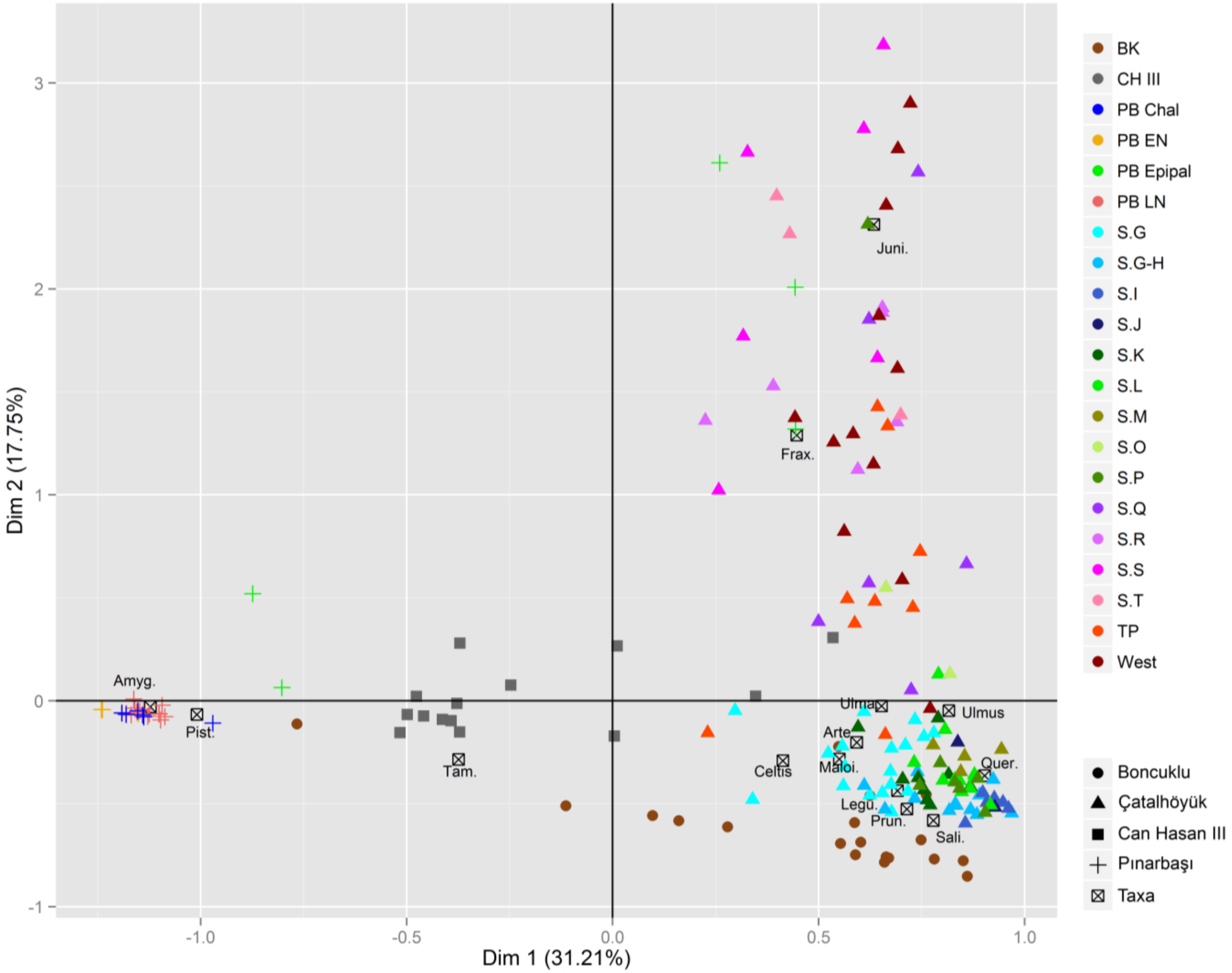


Figure 5.65: Plot of Dimensions 1 and 2, CA run on per sample wood charcoal taxon counts from all sites included in the present study.

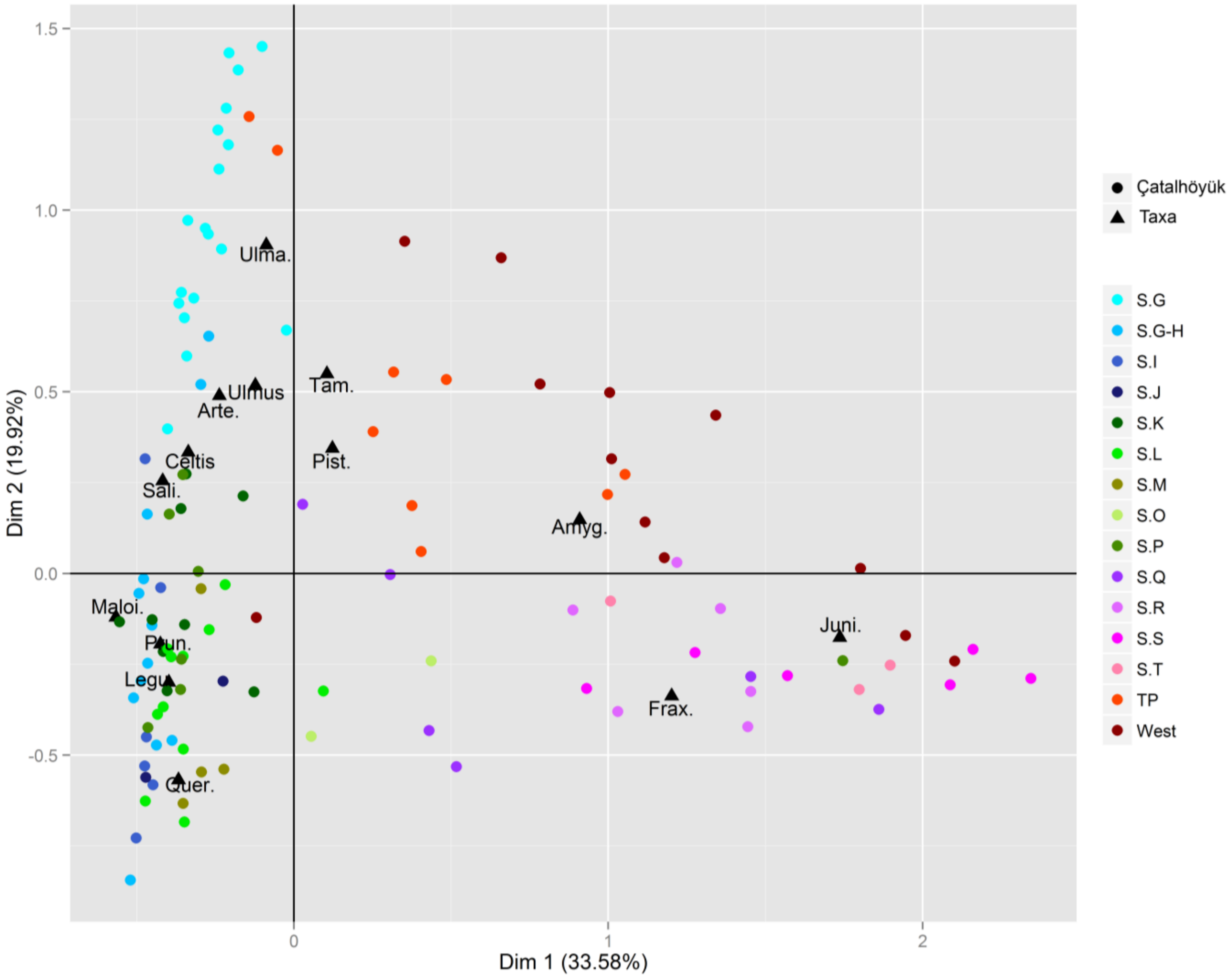


Figure 5.66: Plot of Dimensions 1 and 2, CA run on per sample wood charcoal taxon counts from Çatalhöyük (dispersed contexts).

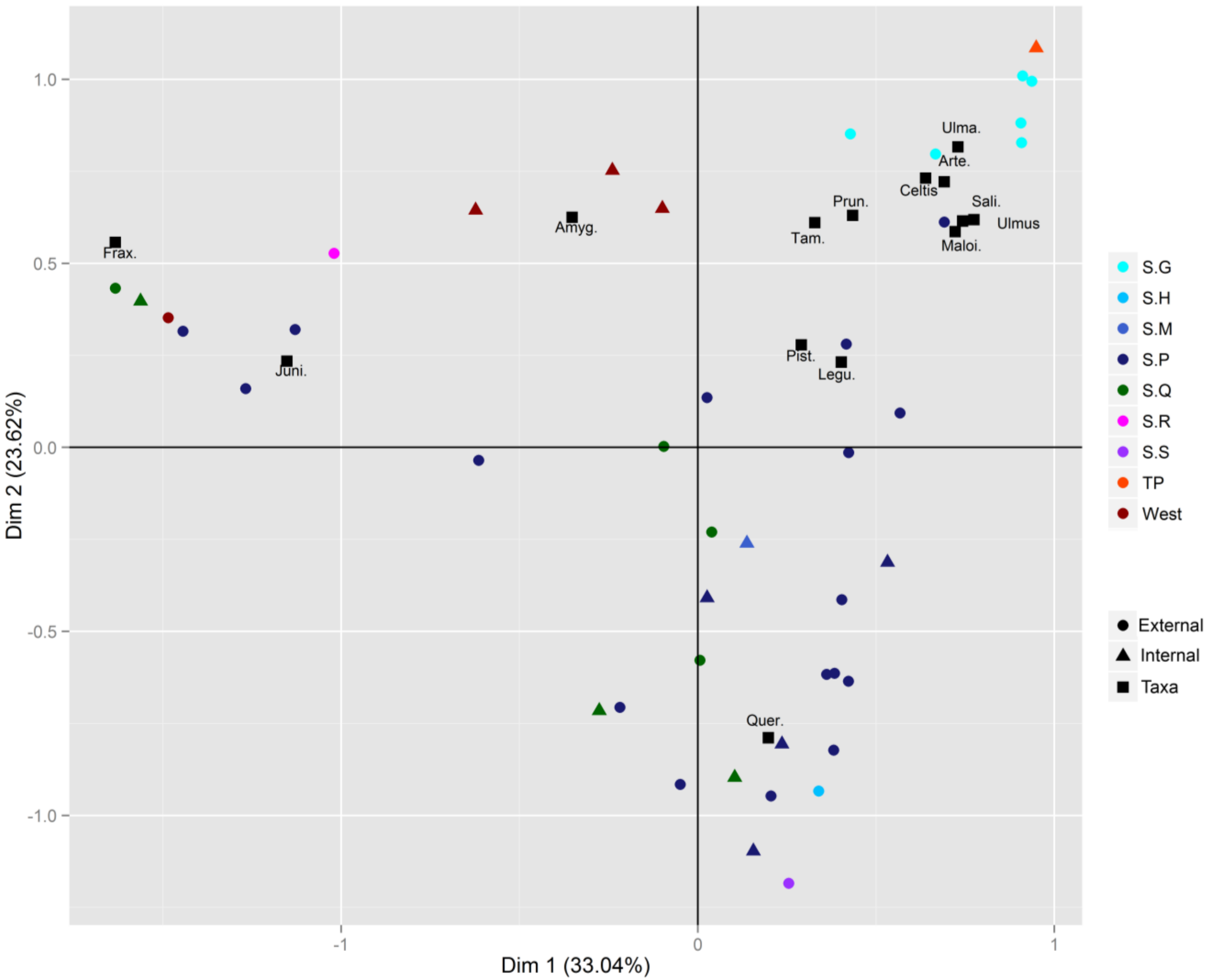


Figure 5.67: Plot of Dimensions 1 and 2, CA run on per sample wood charcoal taxon counts from Çatalhöyük (primary fuel waste deposits).

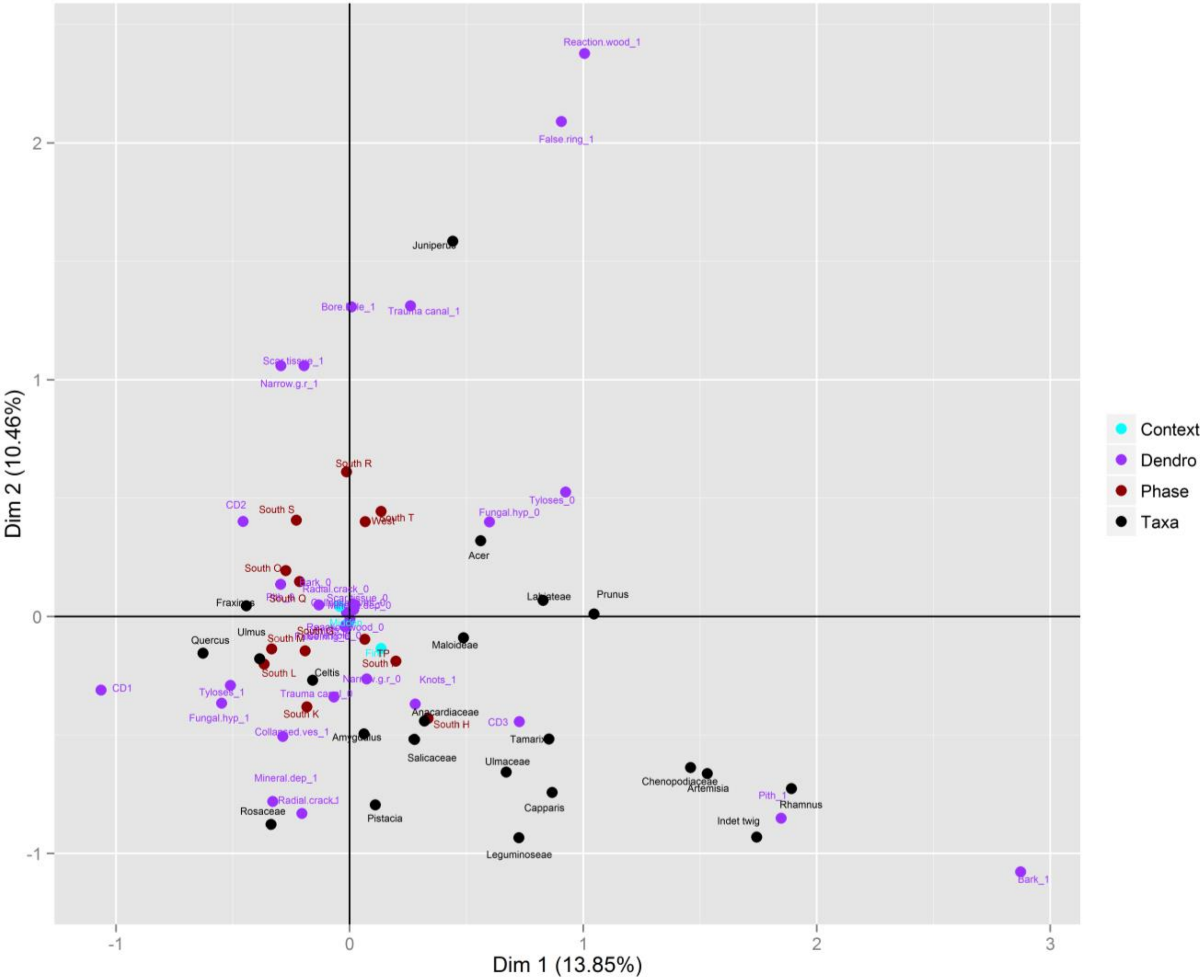


Figure 5.68: Plot of variables (Dimensions 1 and 2), MCA run on dendro-ecological features recorded for Çatalhöyük specimens.

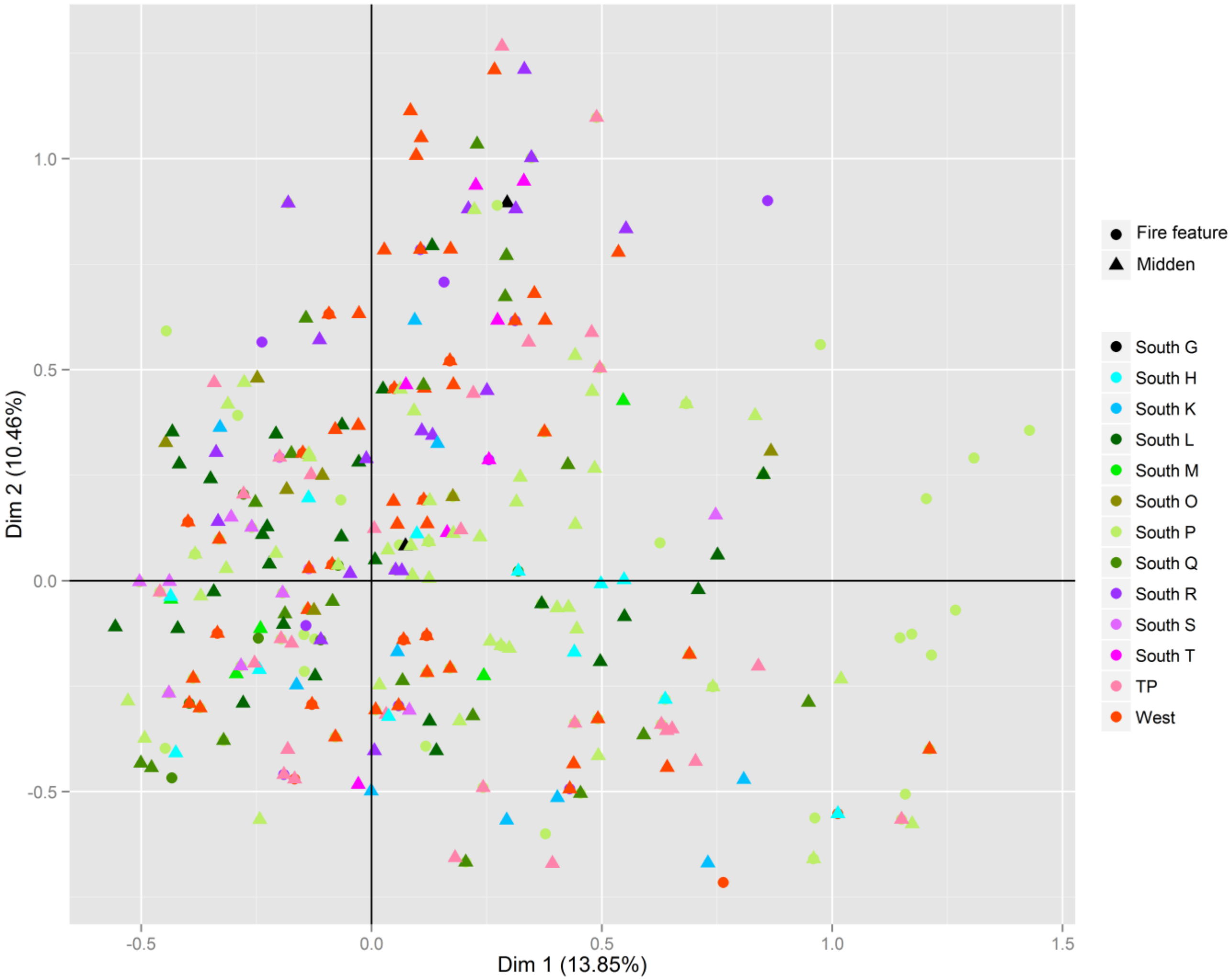


Figure 5.69: Plot of individuals, (Dimensions 1 and 2), MCA run on dendro-ecological features recorded for Çatalhöyük specimens.

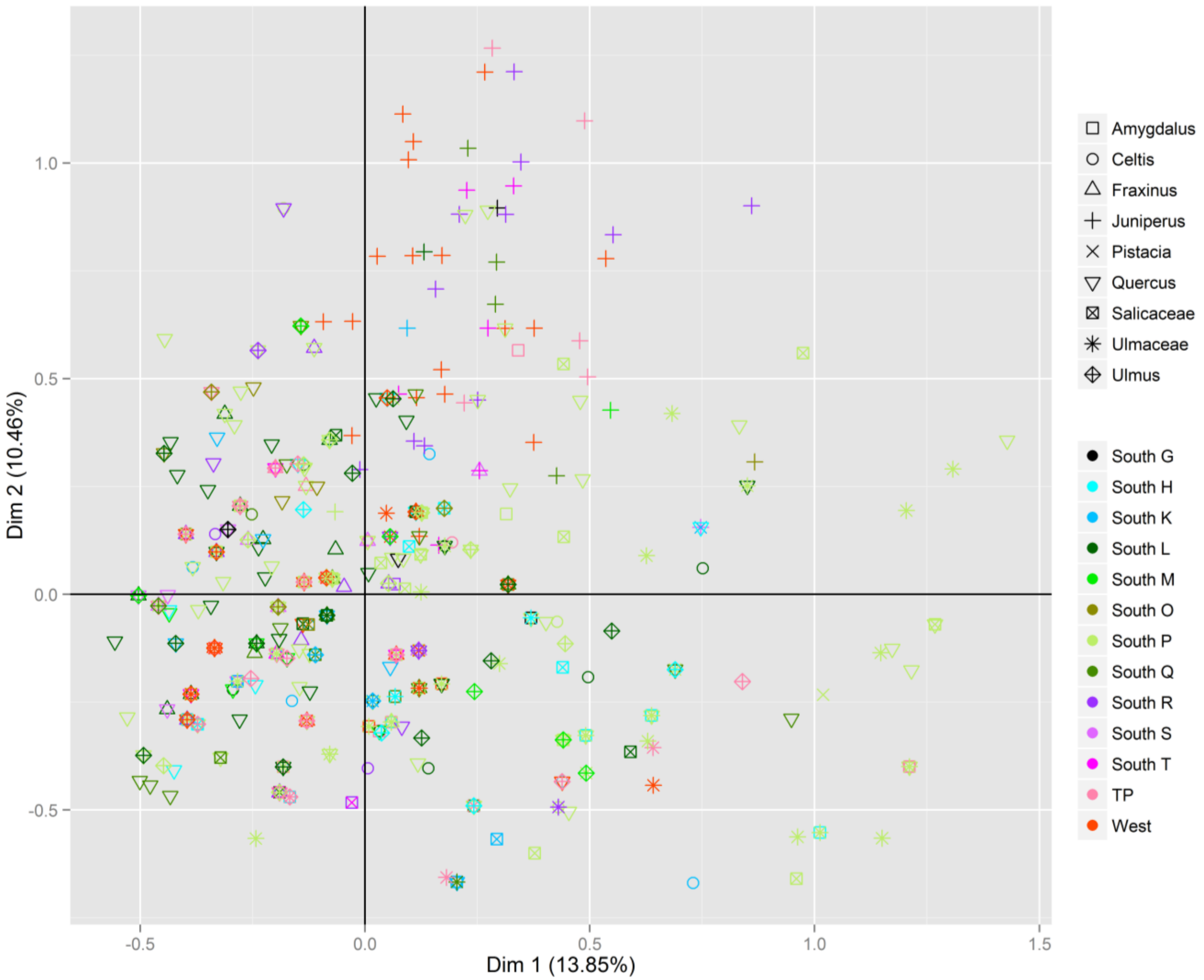


Figure 5.70: Plot of individuals, (Dimensions 1 and 2), MCA run on dendro-ecological features recorded for Çatalhöyük specimens.

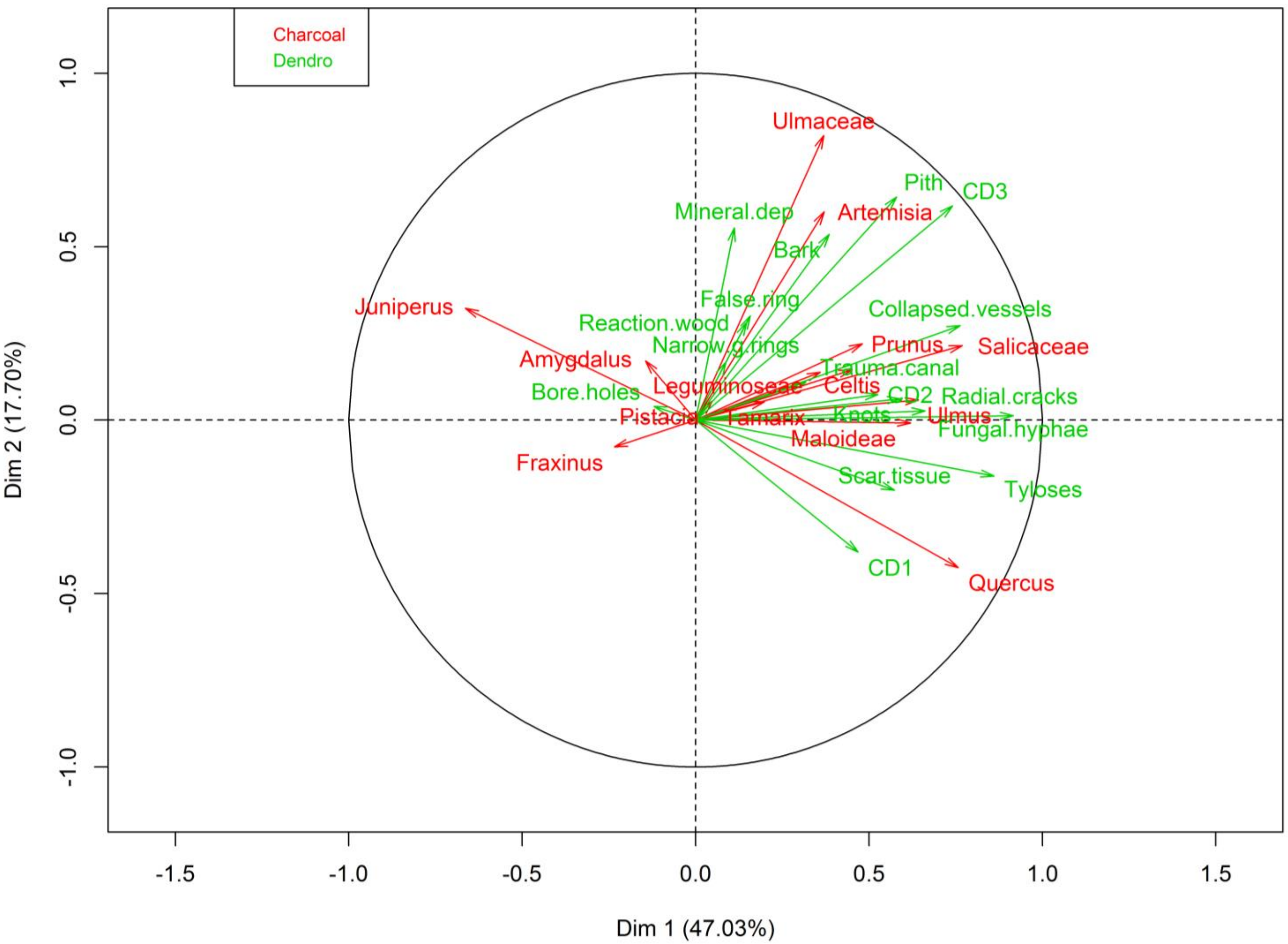


Figure 5.71: Plot of variables (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dendro-ecological feature presence counts from Çatalhöyük (dispersed and primary fuel waste deposits).

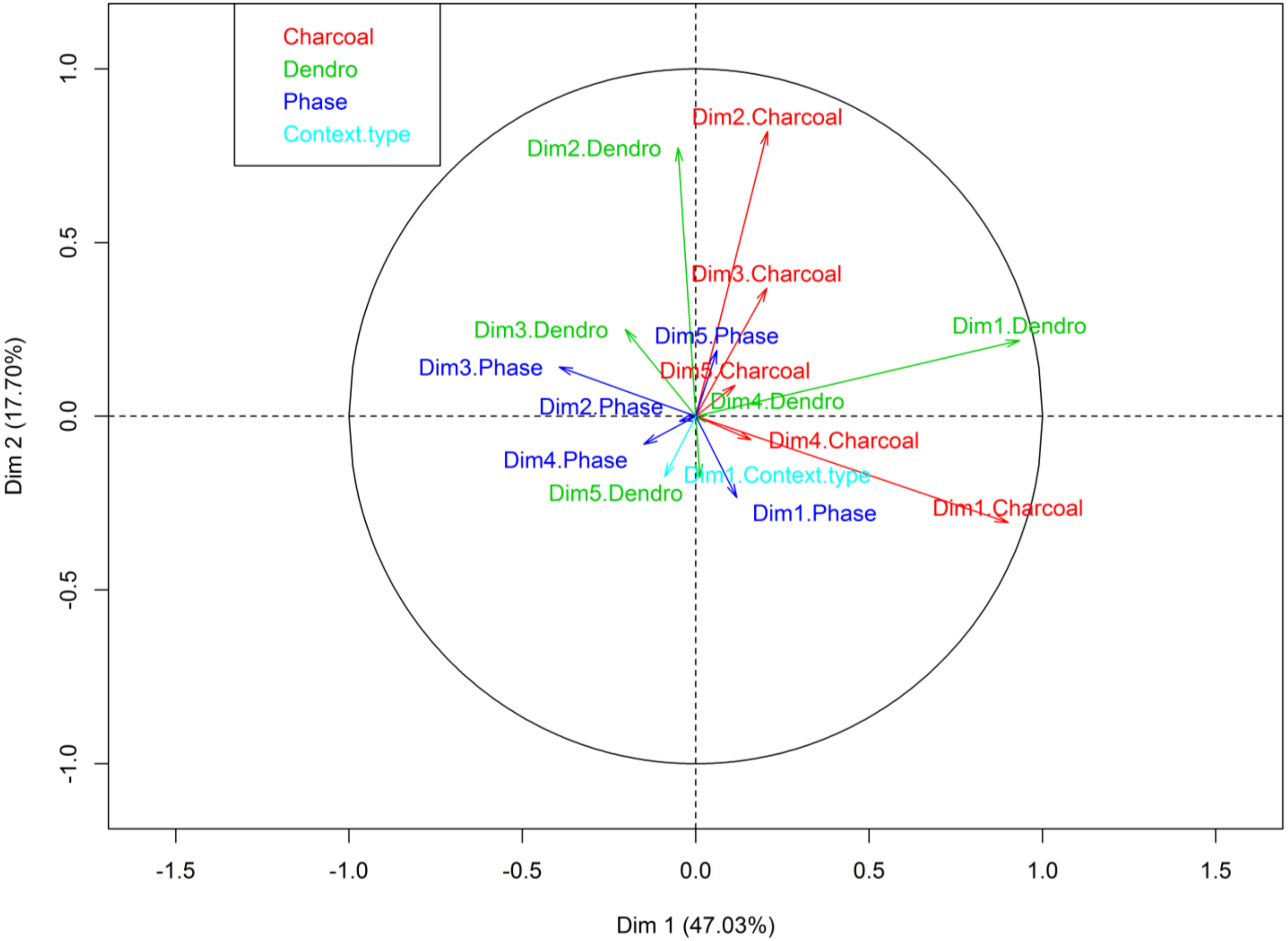


Figure 5.72: Plot of groups (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dendro-ecological feature presence counts from Çatalhöyük (dispersed and primary fuel waste deposits).

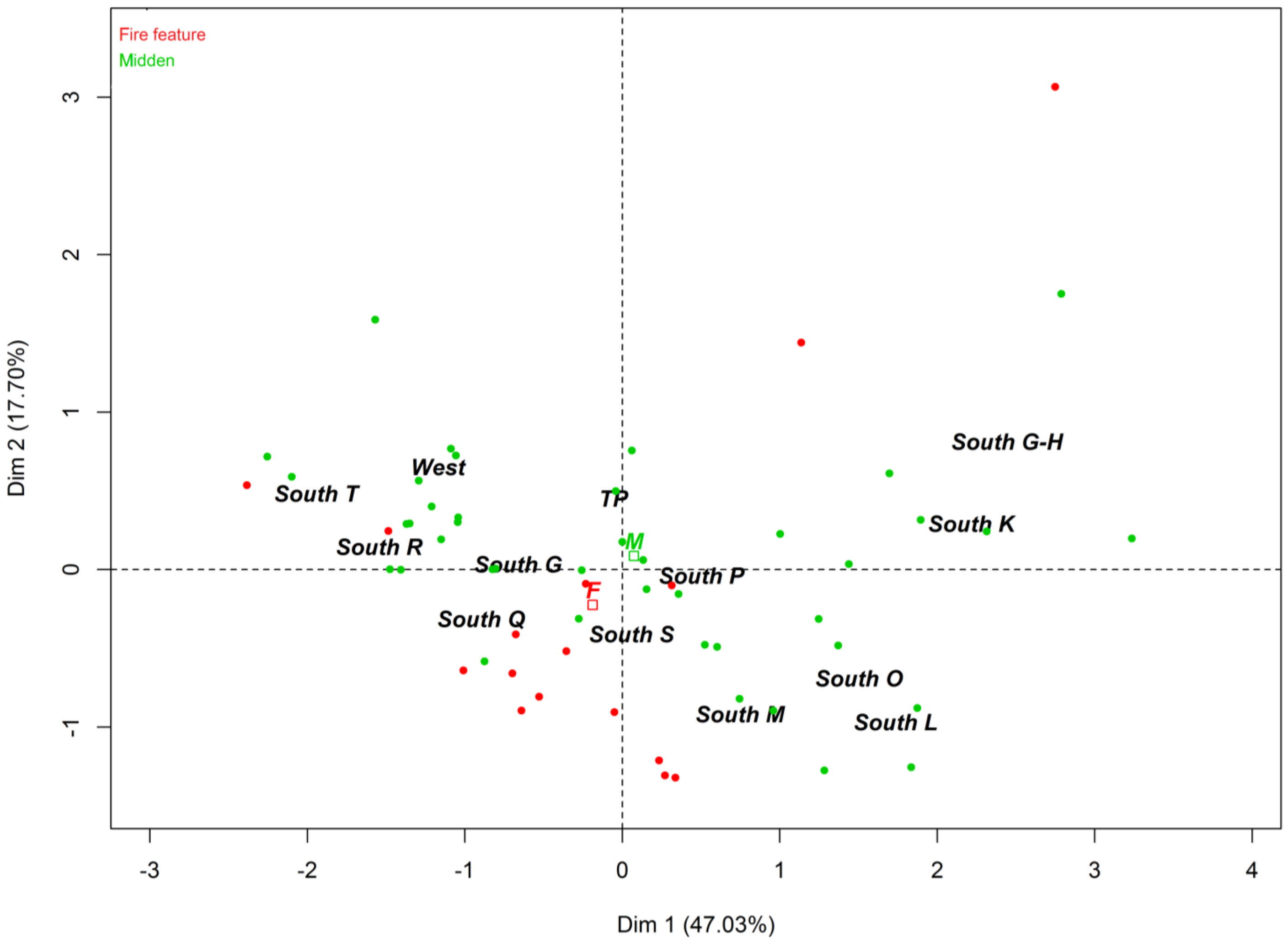


Figure 5.73: Plot of individual samples according to context type (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dendro-ecological feature presence counts from Çatalhöyük (dispersed and primary fuel waste deposits).

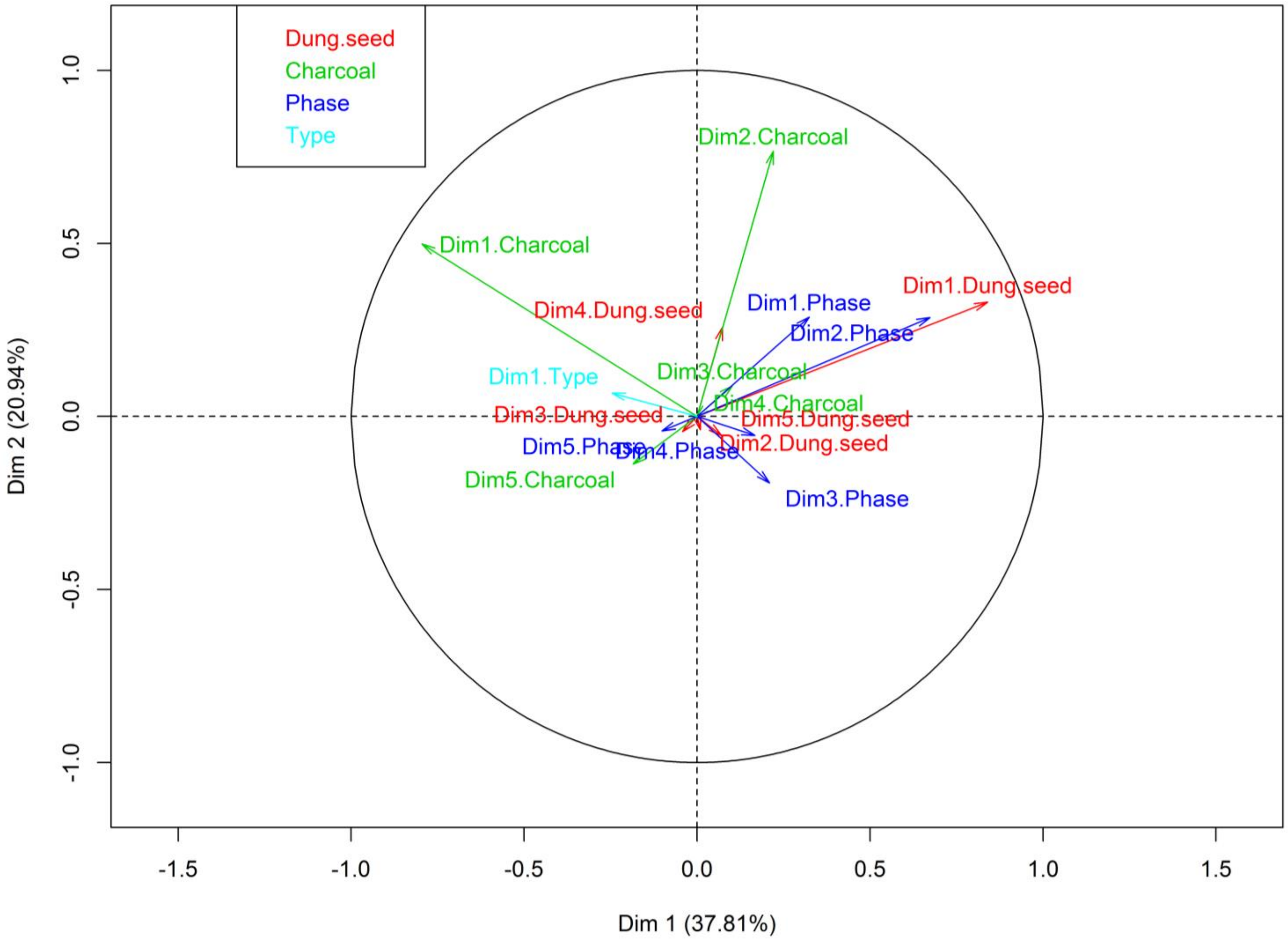


Figure 5.74: Plot of groups (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (primary fuel waste deposits).

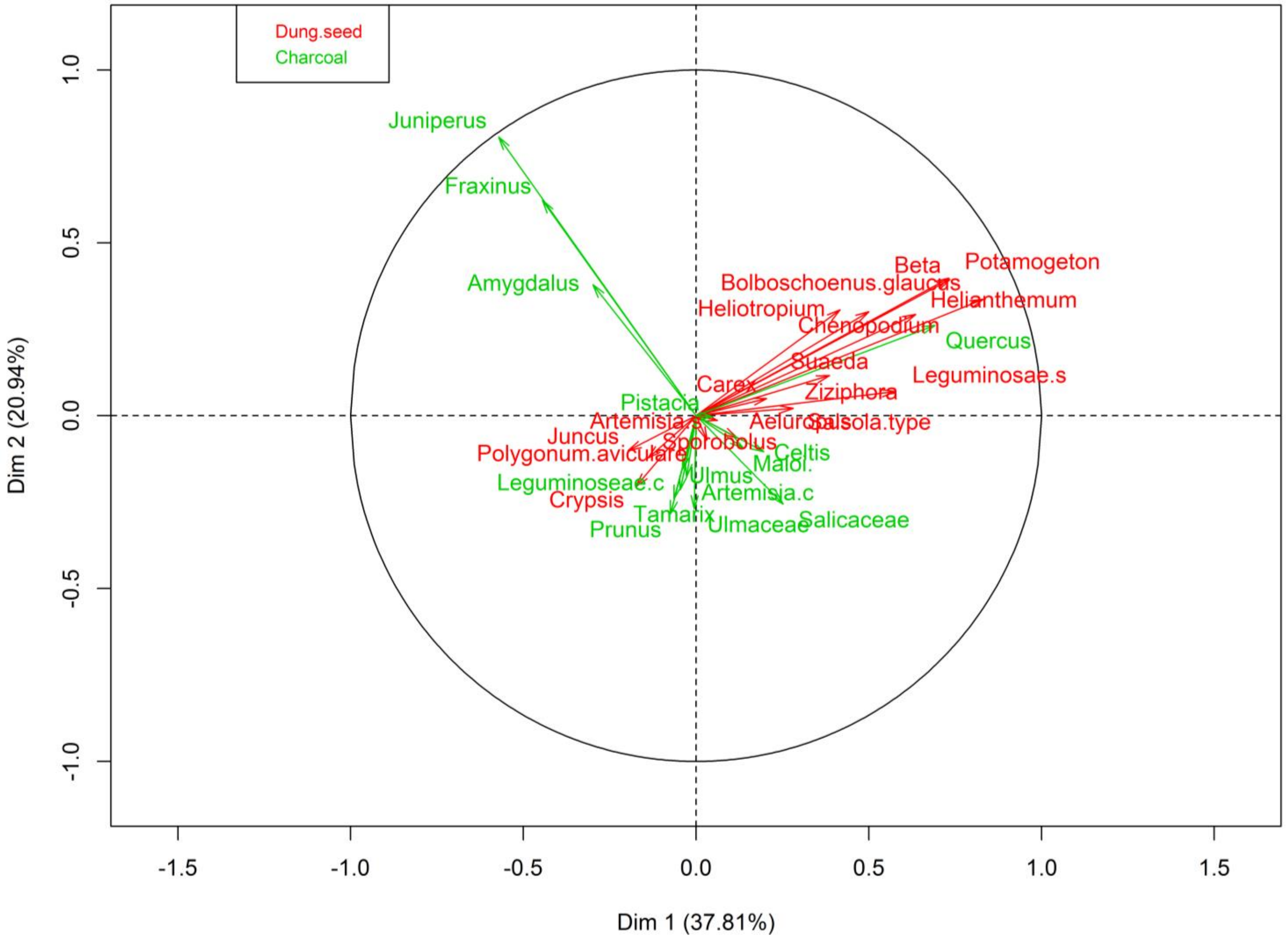


Figure 5.75: Plot of variables (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (primary fuel waste deposits).

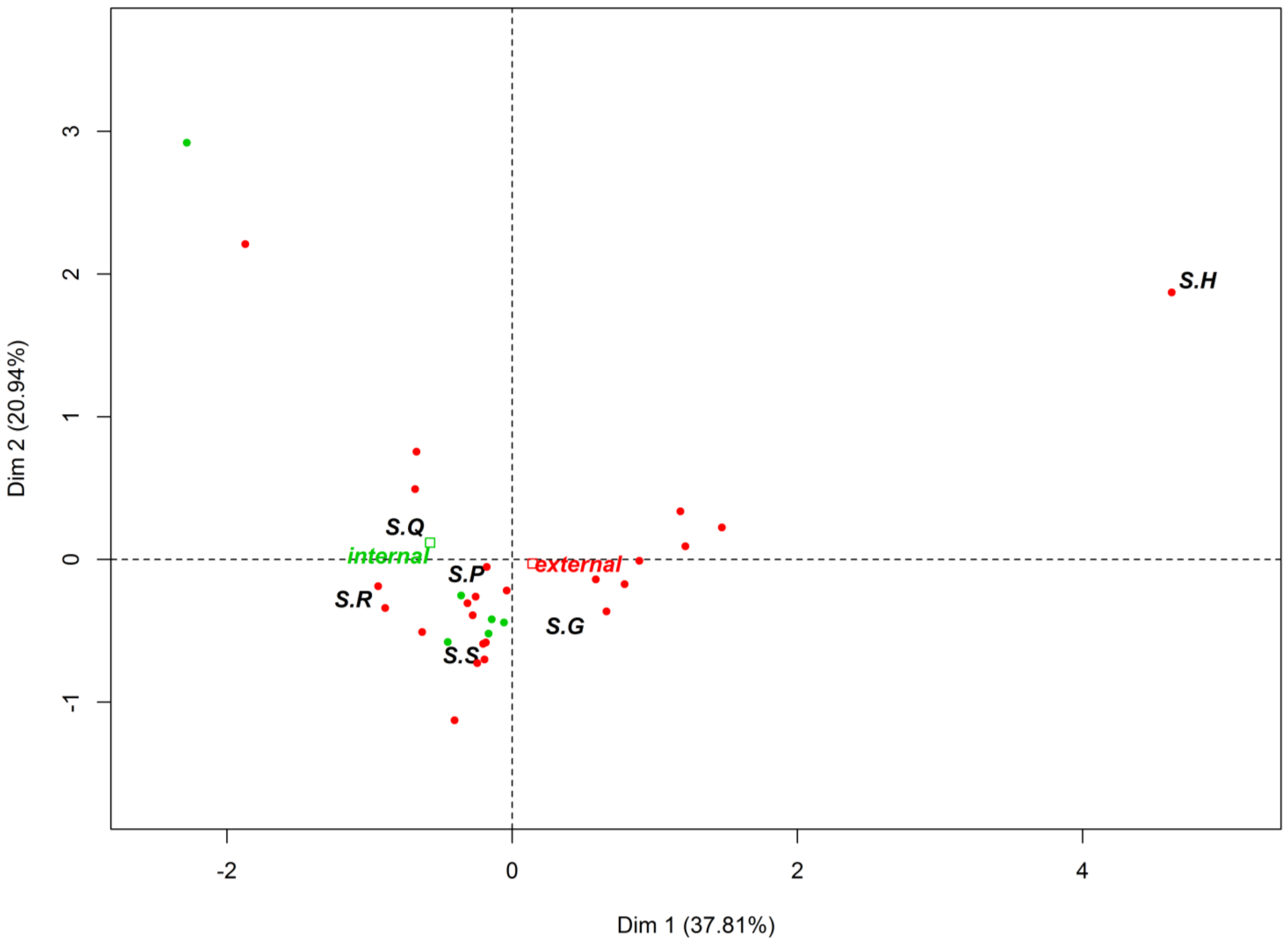


Figure 5.76: Plot of individual samples (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (primary fuel waste deposits). Coded according to location (external, internal) of deposit.

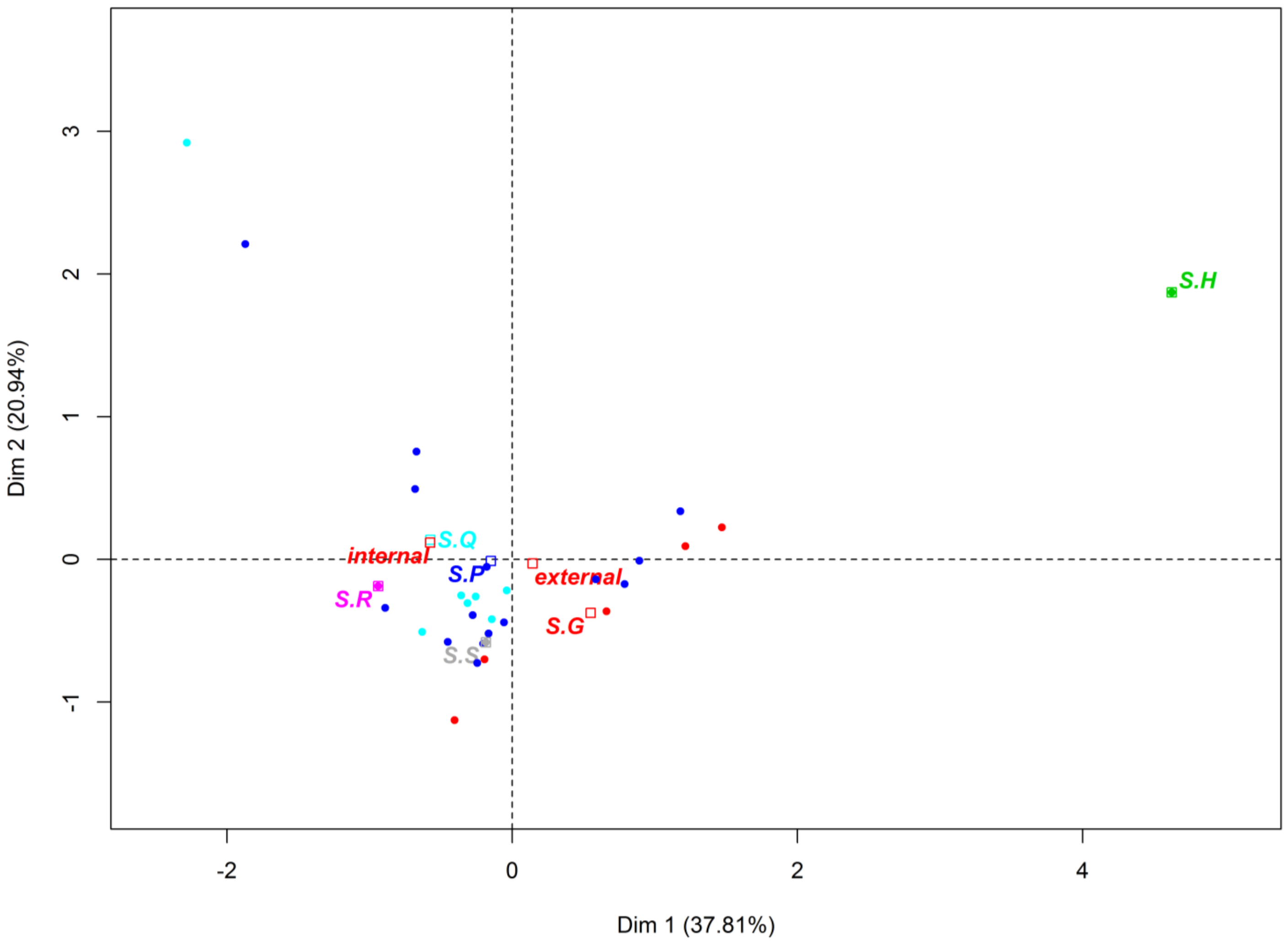


Figure 5.77: Plot of individual samples (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (primary fuel waste deposits). Plotted according to phases.

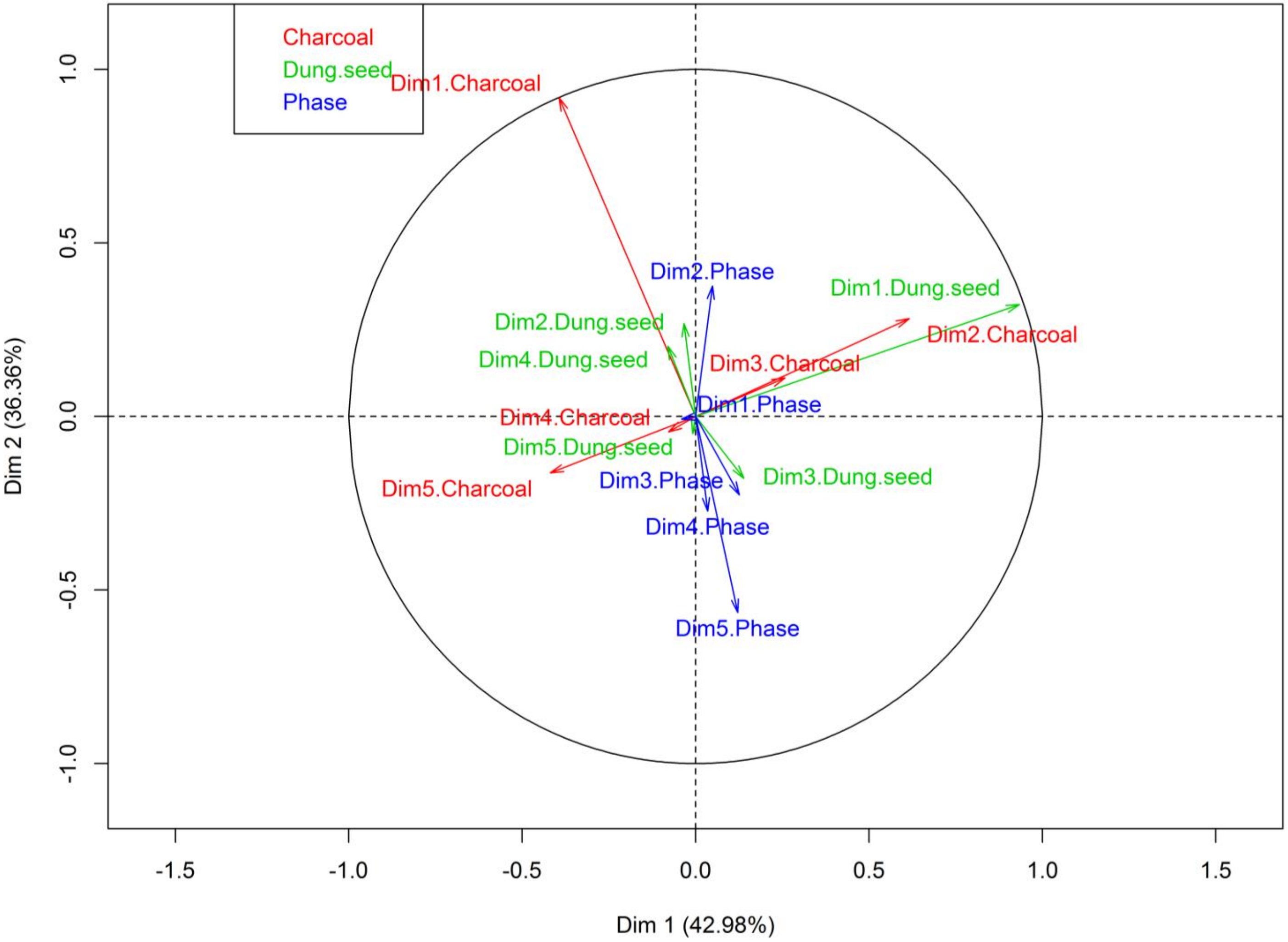


Figure 5.78: Plot of groups (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (dispersed contexts).

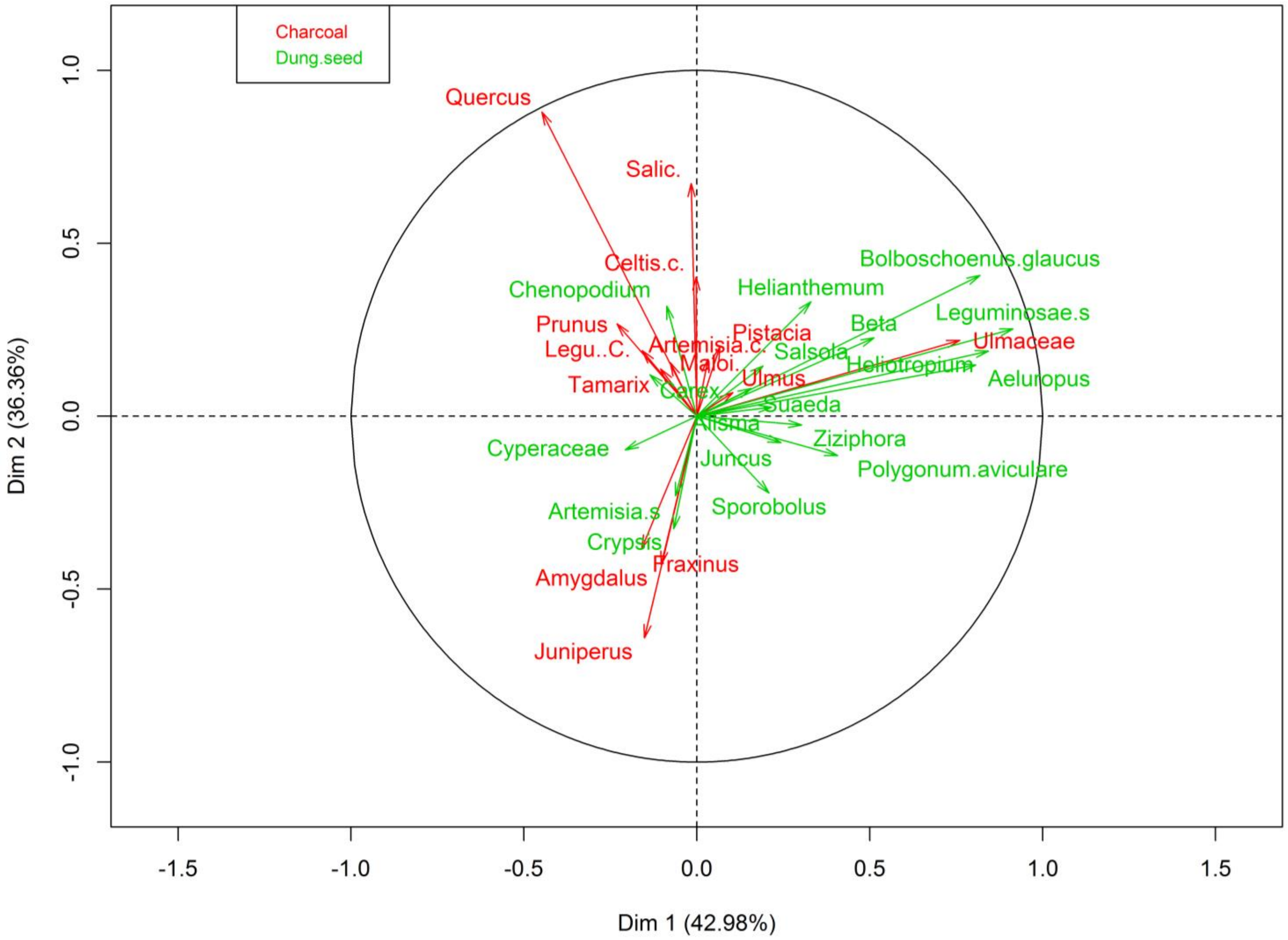


Figure 5.79: Plot of variables (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (dispersed contexts).

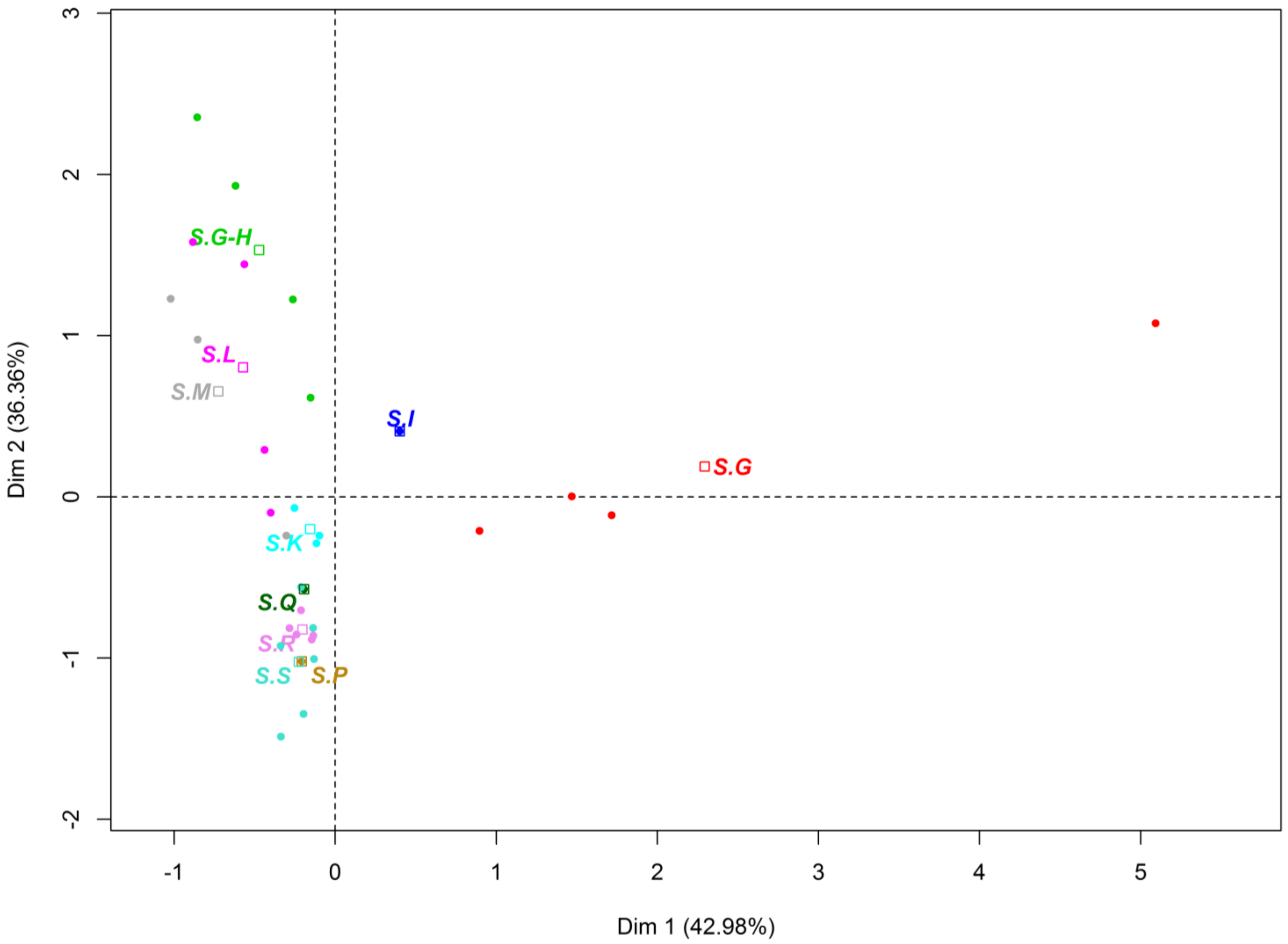


Figure 5.80: Plot of individual samples (Dimensions 1 and 2), MFA run on per sample wood charcoal taxon and dung-derived seed counts from Çatalhöyük (dispersed contexts). Plotted according to phase.

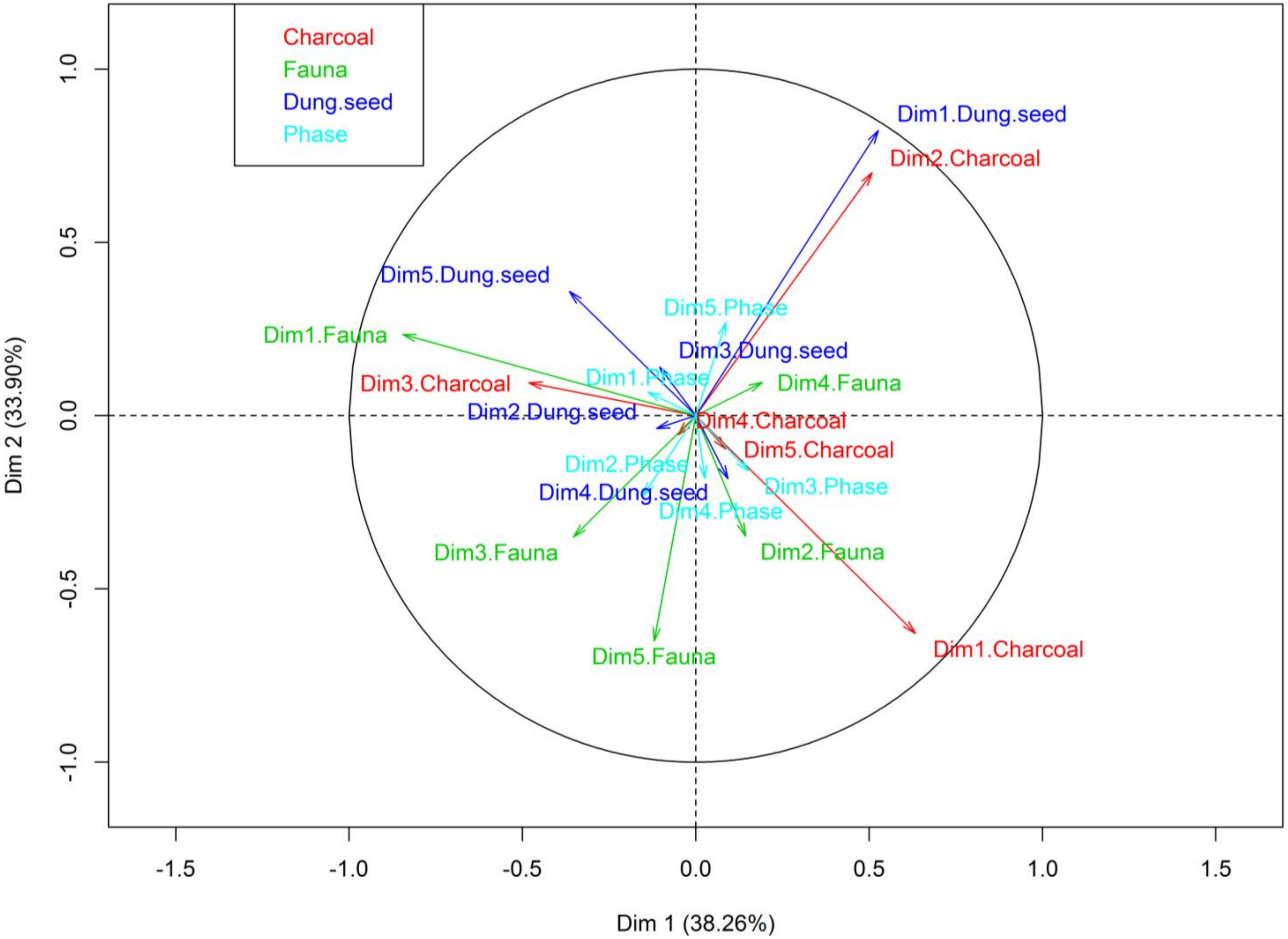


Figure 5.81: Plot of groups (Dimensions 1 and 2), MFA run on per phase wood charcoal taxon and dung-derived seed and faunal taxon (by NISP) counts from Çatalhöyük.

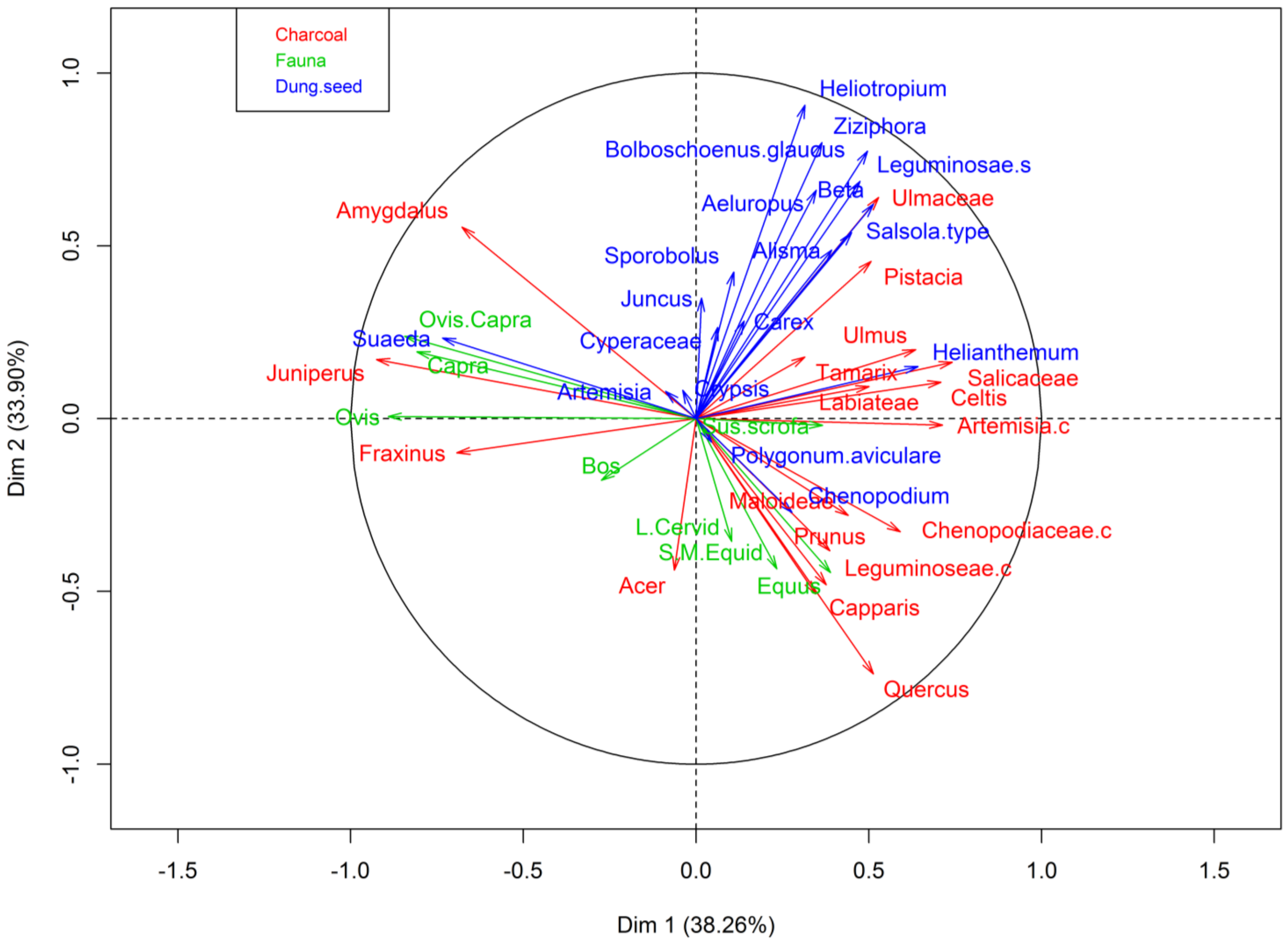


Figure 5.82: Plot of variables (Dimensions 1 and 2), MFA run on per phase wood charcoal taxon and dung-derived seed and faunal taxon (by NISP) counts from Çatalhöyük.

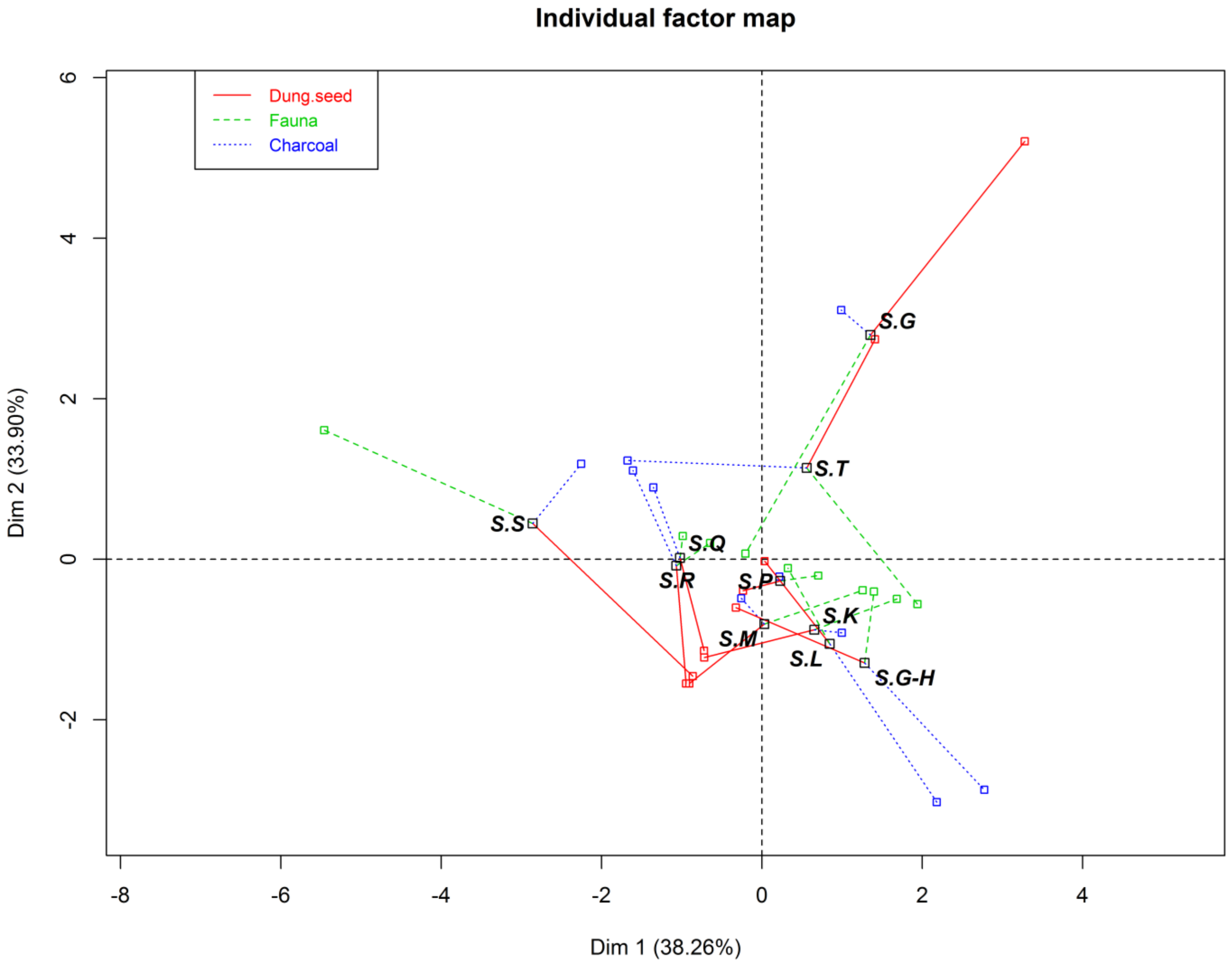


Figure 5.83: Plot of individual phases (Dimensions 1 and 2), MFA run on per phase wood charcoal taxon and dung-derived seed and faunal taxon (by NISP) counts from Çatalhöyük. Centre point represents the mean-placement of phases, partial points are plotted and connected according to group datasets.

Appendix: Wood Anatomical Descriptions

Anatomical description	Family	Genus
	Cupressaceae	*Juniperus*
Transverse Section	Growth rings distinct, generally very narrow. Resin canals absent or infrequent (traumatic). Transition from early wood to late wood gradual.	
Radial Longitudinal Section	Rays homogeneous, composed of parenchyma cells only (ray tracheids absent). Transversal ray walls thick, tangential walls thin with nodules. Indentures present at the junction of longitudinal and horizontal walls. Early wood cross-fields with 1-4 cypressoid and/or taxodioid pits.	
Tangential Longitudinal Section	Rays exclusively uniseriate, 1-5 cells high on average.	
Anatomical description	**Family**	**Genus**
	Pinaceae	*Pinus nigra* type
Transverse Section	Growth rings distinct. Resin canals present, frequent. Transition from early wood to late wood abrupt.	
Radial Longitudinal Section	Rays heterogeneous, composed of parenchyma cells and ray tracheids. Ray tracheid walls distinctly dentate. Early wood cross-fields with 1-2 large, fenestriform pits.	
Tangential Longitudinal Section	Rays exclusively uniseriate, 8-15 cells high on average. Resin canals present.	
Anatomical description	**Family**	**Genus**
	Aceraceae	*Acer*
Transverse Section	Wood diffuse porous. Growth rings distinct. Ring boundary often marked by a thin band of tangentially flattened fibres. Pores solitary and in short radial multiples of 2-4(6). Rays sometimes flared slightly along the ring boundary.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous, with rare square marginal cells. Marginal vessel-ray pits slightly enlarged. Distinct spiral thickenings on all vessels. Libriform fibres present.	
Tangential Longitudinal Section	Rays uni- (bi-) to 4/5-seriate.	

Anatomical description	Family	Genus
	Anacardiaceae	*Pistacia*
Transverse Section	Wood ring porous. Growth rings distinct. Early wood pores solitary usually arranged in a single row. Late wood pores in radial multiples and clusters, occasionally displaying dendritic arrangement. Tyloses are often conspicuous in early wood pores.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, with one row of square and/or upright marginal cells, often conspicuously enlarged. Vessel-ray pits large and simple. Late wood vessels and tracheids with distinct, conspicuous spiral thickenings.	
Tangential Longitudinal Section	Rays 2/3- to 4/5-seriate. Uniseriate rays very rare, up to 4/5 cells high. Larger rays 10-25 cells high. Resin canals visible inside rays.	

Anatomical description	Family	Genus
	Asteraceae	*Artemisia,* Indet.
Transverse Section	Wood diffuse porous. Growth rings indistinct. Pores in radial multiples of 3 or more, often arranged in long radial files.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, with few rows of central procumbent cells bordered by multiple rows of square and/or upright cells, irregularly shaped. Spiral thickenings infrequent.	
Tangential Longitudinal Section	Rays uni- to 5-seriate (commonly 3 to 5-seriate). Sheath cells present.	

Anatomical description	Family	Genus
	Capparaceae	*Capparis*
Transverse Section	Wood diffuse to semi-ring porous. Growth rings indistinct to fairly distinct. Larger pores are mostly solitary or in radial multiples and clusters; smaller (narrower) pores are arranged mostly in clusters. Pore groups are often tangentially oriented.	
Radial Longitudinal Section	Perforation plates simple. Rays generally homogeneous, sometimes with square marginal cells. Vessels often with irregular axial orientation.	
Tangential Longitudinal Section	Rays 4- to 6-seriate, often irregularly shaped, spindle-shaped, sometimes with sheath cells.	

Anatomical description	Family	Genus
	Chenopodiaceae	Indet.
Transverse Section	Wood with included phloem (foraminate to concentric type). Pores solitary and in radial multiples/clusters arranged to the inside of the included phloem groups.	
Radial Longitudinal Section	Perforation plates simple. Vessels, vascular tracheids and parenchyma storied.	
Tangential Longitudinal Section	Rays generally absent.	

Anatomical description	Family	Genus
	Ericaceae	cf. *Arbutus*
Transverse Section	Wood diffuse to semi-ring porous. Growth rings distinct. Pores numerous, angular to round, solitary and in short radial files. 2-3 rows of fibres flattened along the end of the late wood portion.	
Radial Longitudinal Section	Perforation plates mostly simple (scalariform plates with 1-4 bars on very narrow vessels were not observed in the single fragment identified as cf. *Arbutus* from Boncuklu; see also Fig. 5.27). Rays heterogeneous, with a central part of procumbent cells and 1-2 rows of square and upright marginal cells. Conspicuous spiral thickenings.	
Tangential Longitudinal Section	Rays bi- to 3(4) seriate, short, spindle-shaped.	

Anatomical description	Family	Genus
	cf. Euphorbiaceae	Indet.
Transverse Section	Wood diffuse porous. Pores solitary and in radial multiples/groups/clusters.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous with multiple rows of large square and upright cells interspersed with few rows of procumbent cells. Vessel-ray pits bordered and enlarged.	
Tangential Longitudinal Section	Rays uni- to biseriate.	

Anatomical description	Family	Genus
	Fagaceae	*Quercus*
Transverse Section	Wood ring porous. Growth rings distinct. Early wood pores very large, nearly always solitary. Late wood pores small, solitary and in groups, arranged in a distinctly dendritic pattern.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous. Vessel-ray pits large, with oval to slit-like apertures. Libriform fibres and vasicentric tracheids present.	
Tangential Longitudinal Section	Rays of two distinct sizes: uni- and multiseriate. Multiseriate rays very large, >15 cells wide (normally absent in immature wood and twigs).	

Anatomical description	Family	Genus
	Labiatae	Indet.
Transverse Section	Wood diffuse porous (more rarely semi-ring porous). Growth rings indistinct to fairly distinct. Pores small, solitary, in radial multiples of 2 or more, and in small groups.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous composed of few rows of weakly procumbent central cells and numerous rows of square and upright marginal cells. Vessel-ray pits large, sometimes scalariform. Libriform fibres present.	
Tangential Longitudinal Section	Rays uni-, bi to 3-seriate.	

Anatomical description	Family	Genus
	Leguminosae (cf.Papilionoideae)	Indet.
Transverse Section	Wood semi-ring to ring porous. Growth rings fairly distinct. Early wood pores solitary and in oblique-tangentially oriented groups. Late wood pores in oblique-tangentially oriented groups and clusters.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous to heterogenous, with 1-2 rows of square and/or upright marginal cells. Parenchyma and vessels storied together with vessel elements. Inter-vessel pits vestured. Libriform fibres and vascular tracheids present. Conspicuous spiral thickenings on narrower vessel elements and tracheids.	
Tangential Longitudinal Section	Rays bi- to 3-seriate	

Anatomical description	**Family**	**Genus**
	Maloideae	
Transverse Section	Wood diffuse porous. Growth rings distinct. Pores relatively small, solitary, numerous, evenly distributed.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous. to slightly heterogeneous with one row of square marginal cells. Vessel-ray pits large. Fibre tracheids present. Faint spiral thickenings often present on vessel tails and on tracheids.	
Tangential Longitudinal Section	Rays mostly uni- to biseriate (rarely 3-seriate)	

Anatomical description	**Family**	**Genus**
	Oleaceae	*Fraxinus*
Transverse Section	Wood ring porous. Growth rings distinct. Early wood pores large, solitary or more often in radial multiples of 2–3, rarely clustered. Late wood pores small, in radial multiples of 2 or rarely in very small clusters.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous to heterogeneous, composed of a central part of procumbent cells and a single row of square marginal cells. Vessel-ray and intervessel pits small to minute. Libriform fibres present.	
Tangential Longitudinal Section	Rays bi- to 3-seriate (rarely 4-seriate)	

Anatomical description	**Family**	**Genus**
	Rhamnaceae	*Rhamnus*
Transverse Section	Wood diffuse to semi-ring porous. Growth rings fairly distinct. Pores solitary and in small groups, clustered with vascular tracheids and parenchyma arranged in dendritic bands. Parenchyma paratracheal. Banded parenchyma (1-3 cell wide bands) at the beginning of the early wood portion.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, with 1-2 or more rows of square and/or upright cells and multiple rows of procumbent cells. Vessel-ray pits enlarged. Spiral thickenings prominent. Libriform fibres present.	
Tangential Longitudinal Section	Rays mostly bi- to 3-seriate.	

Anatomical description	Family	Genus
	Rhamnaceae	cf. *Ziziphus/Paliurus?*
Transverse Section	Wood diffuse porous. Growth rings fairly distinct. Pores large, mostly in long radial multiples, and solitary.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous to slightly heterogeneous, composed mostly of square, and rectangular procumbent cells.	
Tangential Longitudinal Section	Rays bi- to 3-seriate.	

Anatomical description	Family	Genus
	Rosaceae	*Amygdalus* (type 1)
Transverse Section	Wood ring porous. Growth rings distinct. Early wood pores large, either solitary or in short radial multiples. Late wood pores mostly solitary. Tyloses abundant.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, composed of a central portion of procumbent cells and weakly square marginal cells. Spiral thickenings common on narrow, late wood vessels, very infrequent on larger early wood vessels.	
Tangential Longitudinal Section	Rays (1)3-5(6) seriate.	

Anatomical description	Family	Genus
	Rosaceae	*Amygdalus* (type 2)
Transverse Section	Wood ring porous. Growth rings distinct. Pores densely packed. Early wood pores large, either solitary or in short radial multiples. Late wood pores mostly solitary. Tyloses abundant.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, with a central portion of procumbent cells and weakly square marginal cells. Spiral thickenings common on narrow, late wood vessels, very infrequent on larger early wood vessels.	
Tangential Longitudinal Section	Rays uni- and multi-(5-8-10) seriate.	

Anatomical description	**Family**	**Genus**
	Rosaceae	*Prunus*
Transverse Section	Wood diffuse to semi-ring porous. Growth rings distinct. Pores numerous, arranged in short radial multiples and occasionally in small clusters as well.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, with a central portion of procumbent cells and weakly square marginal cells. Spiral thickenings prominent on vessel walls and fibres.	
Tangential Longitudinal Section	Rays mostly bi- to 3seriate (occassionally 4- to 5seriate).	

Anatomical description	**Family**	**Genus**
	Salicaceae	Indet.
Transverse Section	Wood diffuse porous. Growth rings indistinct to fairly distinct. Pores numerous, in short radial multiples and clusters; often solitary (especially in immature wood).	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous to slightly heterogeneous. Vessel-ray pits large and simple. Inter-vessel pits large. Libriform fibres present.	
Tangential Longitudinal Section	Rays uniseriate.	

Anatomical description	**Family**	**Genus**
	Tamaricaceae	*Tamarix*
Transverse Section	Wood ring porous. Growth rings distinct. Pores solitary and in small groups.	
Radial Longitudinal Section	Perforation plates simple. Rays, heterogeneous, with numerous rows of procumbent cells and 1-2 rows of square and upright marginal cells. Vessels and parenchyma storied. Inter-vessel and vessel-ray pits numerous and small. Libriform fibres present.	
Tangential Longitudinal Section	Rays tall and large, 6-7 to 20seriate.	

Anatomical description	Family	Genus
	Ulmaceae	*Celtis*
Transverse Section	Wood ring porous. Growth rings distinct. Early wood pores solitary and in short radial multiples of 2-3, and are usually arranged in a single row. Late wood pores in oblique to tangentially arranged large clusters.	
Radial Longitudinal Section	Perforation plates simple. Rays heterogeneous, with few rows of procumbent cells and numerous rows of square and upright marginal cells (uniseriate rays composed entirely of square and upright cells). Vascular tracheids and libriform fibres present. Distinct spiral thickenings on narrow vessels and tracheids.	
Tangential Longitudinal Section	Rays uniseriate and multiseriate. Sheath cells present.	

Anatomical description	Family	Genus
	Ulmaceae	*Ulmus*
Transverse Section	Wood ring porous. Growth rings distinct. Early wood contains 1-3 rows of pores, solitary and in short radial multiples of 2-3. Late wood pores in oblique to tangentially arranged large clusters. Rays flare slightly along the growth ring boundaries.	
Radial Longitudinal Section	Perforation plates simple. Rays homogeneous to slightly heterogeneous, with 1-2 rows of square and upright marginal cells. Vascular tracheids and libriform fibres present. Distinct spiral thickenings on narrow vessels and tracheids.	
Tangential Longitudinal Section	Rays 4-5 seriate	